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ABSTRACT

Construction One is a programed text on building construction being used in the first term in the School of Architecture, Nova Scotia Technical College. Illustrated throughout with diagramatic line drawings, the text is set up with a pretest, specific work assignments in the text, and a comprehensive post-test. The individualized course is designed to be used in a laboratory setting and is applicable for students with or without any prior knowledge of building construction. (MW)

ED105085

CONSTRUCTION 1

NOVA SCOTIA TECHNICAL COLLEGE SCHOOL OF ARCHITECTURE, HALIFAX, N.S.

ERRATA SHEET

PAGE	
19	Delete "shipping"/substitute "slipping"
34	Delete "Neccessity"/substitute "necessity"
54	Delete "significanly"/substitute "significantly"
58	In choice of foundation (a) add (raft)
60	Delete "only"
71	Delete "form"/ substitute "from"
82	Delete "then"/ substitute "than"
83	Delete commas
84	Delete "foundations"/ substitute "foundation"
88	Delete "namely"/ substitute "naming"
89	Add metal tie (2) (3) Add Gaskets (4)
108	Delete parentheses
119	Delete "accessable"/substitute "accessible"
120	Delete "galvanised"/ substitute "galvanized"
126	A/V presentation numbers - 14A, 14B
126	Delete "anoonometric"/ substitute "axonometric"
135	Delete "compraision"/ substitute "comparison"
136	Delete "excerise"/ substitute "exercise"
154	Delete "cill"/ substitute "sill"
156	Delete "comvined"/ substitute "combined"
157	Delete "hings"/ substitute "hinges"
157	Delete "insightly"/ substitute "unsightly"
167	Delete "inclued"/substitute "included"
167	Delete "sealed"/substitute "scaled"
168	Delete "viser"/ substitute "riser"
173	Reference - page 40
176	Delete "Fule" / substitute "flue"

INTRODUCTION

In early times Mans demand for shelter was very simple. As time progressed and numbers grew he was forced to leave those areas of this Earth where living was sufficiently easy that shelter was unimportant, to areas where satisfactory shelter became a matter of the continuance of life itself.

The technology of providing satisfactory shelter is the technology of Building Construction.

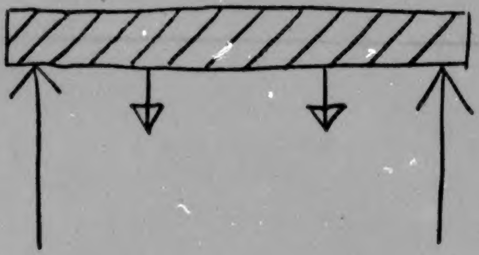
It is the intention of this device to demonstrate the principles of building construction.

Frank Eppell
Halifax, N.S.
September 1973.

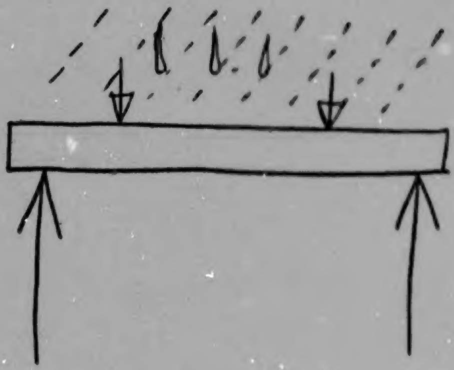
The simplest function of a building is to provide shelter.

To provide shelter there must be elements to enclose space at its most basic level, these elements are horizontal and vertical. The horizontal element above the space is the roof. This horizontal element must exclude the elements and carry loads in the form of snow or water as well as its own weight. The self weight of the roof is called a dead load.

The imposed loads due to snow or water or any other force is called the live load.



dead load



live load

The roof is a element.

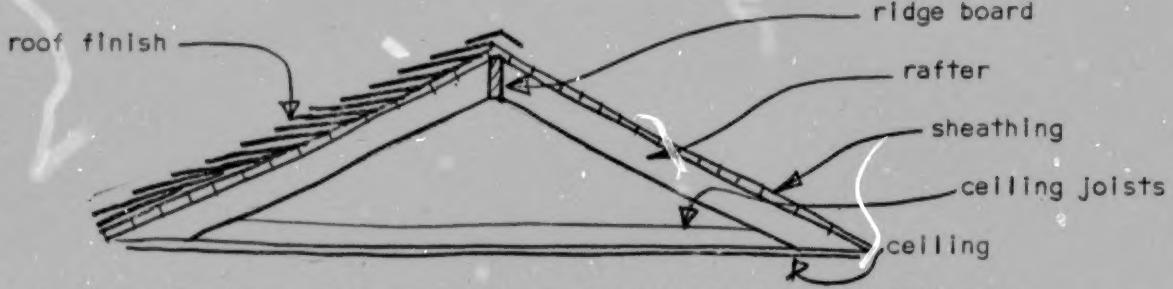
It must support (a) live / (b) dead load.

If you checked (a) turn to page (3)

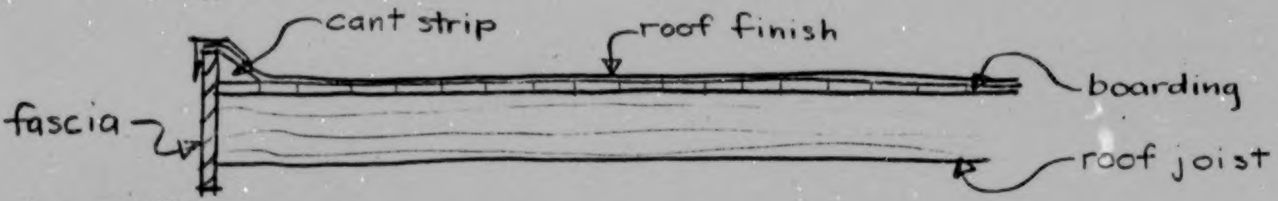
If you checked (b) turn back to page (1)

The roof supports a live load.

The dead load is that load which includes all the materials forming a roof. For example a pitched roof might consist of wood ridge board rafters and ceiling joists, sheathing, roof finish and ceiling.


roof finish
ridge board
rafter
sheathing
ceiling joists
ceiling

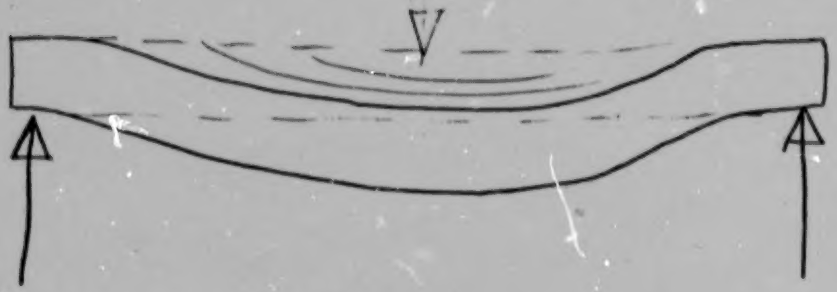
A flat roof might consist of wood roof joists boarding tilt fillet or cant strip, roof finish, ceiling and fascia.


cant strip
roof finish
boarding
fascia
roof joist

The load bearing member in a wood flat roof is known as a (a) (rafter) (b) (joist) (Check one)

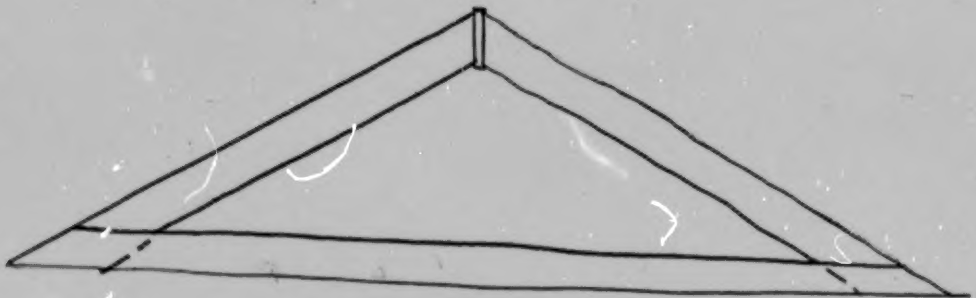
If you checked (a) Turn to page 6)
If you checked (b) Turn to page 5)

The carrying of a load on any member will cause it to move downwards. This is known as deflection.



The load bearing member is a wood flat roof is known as a joist.

The inclined member is known as a rafter.



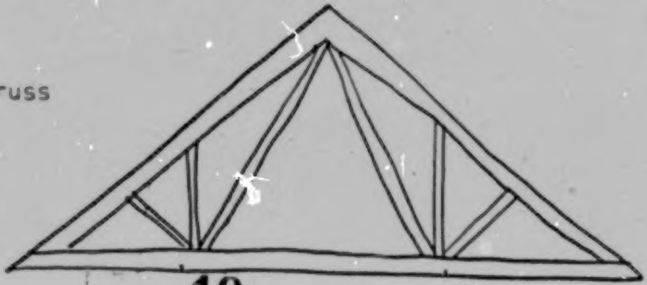
Rafters are frequently used in conjunction with a support known as a truss.

A truss consists of a series of members braced to provide greater support than is possible with the same materials covering greater spans.

The truss uses the principle of triangulation, as well as shortening the effective span of the members

The joist is a simple member to span space.

Typical Truss



Turn to page 5

Movement

Deflection is important in itself, but so far as practical construction is concerned it is just as important to consider the effect upon junctions between similar and dissimilar materials caused by movement.

Movement can be produced in many ways other than deflection. For example a reduction in temperature causes shrinkage, a rise in temperature, expansion. A change in humidity produces movement. And loading, be it caused by natural or artificial means, of course affects the dimensional stability of structure & materials.

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The size of joists to span a given distance carrying a given load is determinable from tables or by calculation.

ROOF JOISTS

Species	Grade	Nominal size	LIVE LOAD 50 lb per sq ft															
			Gypsum Board or Plastered Ceiling								Other Ceilings							
			Joist spacing								Joist spacing							
			12 in.		16 in.		20 in.		24 in.		12 in.		16 in.		20 in.		24 in.	
		inches	ft	in.	ft	in.	ft	in.	ft	in.	ft	in.	ft	in.	ft	in.	ft	in.
Eastern Spruce (5) Balsam Fir Eastern Hemlock	No. 1 (Construction)	2 x 6	9	0	8	2	7	7	7	2	10	4	9	0	8	1	7	5
		2 x 8	12	4	11	2	10	5	9	10	14	1	12	4	11	0	10	1
		2 x 10	15	7	14	2	13	1	12	5	17	10	15	7	14	0	12	8
		2 x 12	18	8	17	0	15	5	14	11	21	5	19	5	18	0	16	4
	No. 2 (Standard)	2 x 6	9	0	7	10	7	0	6	5	9	0	7	10	7	0	6	5
		2 x 8	12	4	11	2	10	5	9	6	13	5	11	7	10	5	9	6
		2 x 10	15	7	14	2	13	1	12	1	17	1	14	10	13	4	12	1
		2 x 12	18	8	17	0	15	8	14	11	21	5	19	5	17	7	16	0
Jack Pine (4)	No. 1 (Construction)	2 x 6	9	4	8	5	7	10	7	5	10	7	9	8	8	8	7	11
		2 x 8	12	8	11	6	10	8	10	0	14	6	13	2	11	10	10	10
		2 x 10	15	0	14	7	13	6	12	8	18	5	16	8	15	0	13	8
		2 x 12	19	2	17	7	16	2	15	2	22	1	20	0	18	7	17	6
	No. 2 (Standard)	2 x 6	9	4	8	5	7	6	6	11	9	8	8	5	7	6	6	1
		2 x 8	12	8	11	6	10	8	10	0	14	5	12	5	11	1	10	2
		2 x 10	16	0	14	7	13	6	12	8	18	5	15	11	14	2	13	6
		2 x 12	19	2	17	7	16	2	15	2	22	1	20	0	18	7	17	2
White Pine Red Pine	No. 1	2 x 6	8	8	7	11	7	5	6	11	9	10	8	6	7	7	6	11
		2 x 8	11	11	10	10	10	0	9	6	13	5	11	7	10	5	9	6
		2 x 10	15	1	13	8	12	8	12	0	17	0	14	8	13	1	12	0
		2 x 12	18	1	16	5	15	2	14	5	20	10	18	10	16	10	15	5
	Merchantable and No. 2	2 x 6	8	8	7	10	7	0	6	5	9	0	7	10	7	0	6	5
		2 x 8	11	11	10	10	9	8	8	11	12	7	10	11	9	8	8	11
		2 x 10	15	1	13	8	12	6	11	5	16	1	13	11	12	6	11	5
		2 x 12	18	1	16	5	15	2	14	5	20	10	18	4	16	6	15	0
	No. 1 Dimension	2 x 6	8	6	7	5	6	7	6	0	8	6	7	5	6	7	6	0
		2 x 8	11	11	10	5	9	4	8	6	12	0	10	5	9	4	8	6
		2 x 10	15	1	13	8	12	6	11	5	16	1	13	11	12	6	11	5
		2 x 12	18	1	16	5	15	2	14	5	20	4	17	6	15	9	14	5
	No. 2 Dimension (3)	2 x 6	6	7	5	8	5	1	4	7	6	7	5	8	5	1	4	7
		2 x 8	9	4	8	0	7	2	6	6	9	4	8	0	7	2	6	6
		2 x 10	12	8	11	0	9	11	9	0	12	8	11	0	9	11	9	0
		2 x 12	15	10	13	8	12	5	11	2	15	10	13	8	12	5	11	2
Poplar	No. 1 (Construction)	2 x 6	8	3	7	11	7	5	6	11	9	10	8	6	7	7	6	11
		2 x 8	11	11	10	10	10	0	9	6	13	5	11	7	10	5	9	6
		2 x 10	15	1	13	8	12	8	12	0	17	0	14	8	13	1	12	0
		2 x 12	18	1	16	5	15	2	14	5	20	10	18	10	16	10	15	5
	No. 2 (Standard)	2 x 6	8	6	7	5	5	7	6	0	8	6	7	5	6	7	6	0
		2 x 8	11	11	10	10	9	8	8	11	12	6	10	11	9	8	8	11
		2 x 10	15	1	13	8	12	6	11	5	16	1	13	11	12	6	11	5
		2 x 12	18	1	16	5	15	2	14	5	20	10	18	4	16	6	15	0

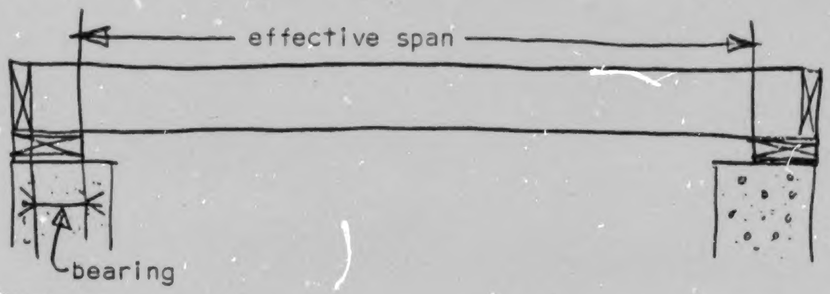
It can be seen that the load carrying capacities of wood varies with species.

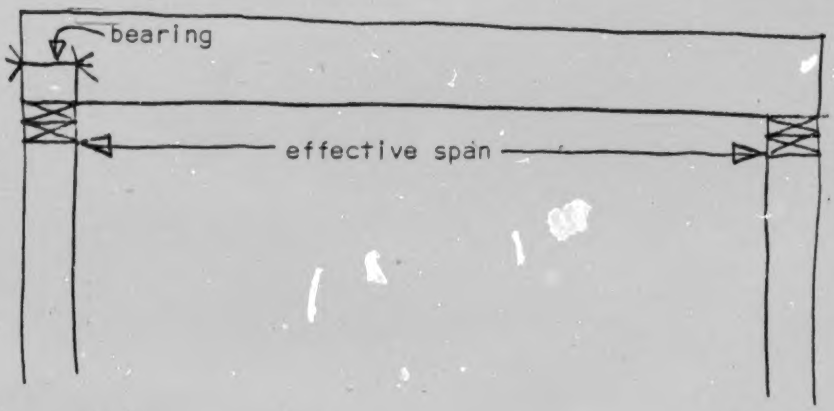
In the Maritime provinces the most used lumber is naturally that produced locally, that is, Eastern Spruce, and White Pine.

Most other species can be obtained, but are more expensive. In particular, Douglas Fir is a preferred alternative for longer spans, as local lumber suffers from limitation in available sizes.

The effective span is the distance between supports, and not the actual length of the member.

The ends of the joists are supported at what is known as the bearing. The bearing must not be less than 2", and preferably more.


effective span
bearing


bearing
effective span

The effective span (is) (is not) the actual length of a joist.

a. is ______________________________

b. is not ______________________________

If you checked a. turn to page 9

If you checked b. turn to page 13

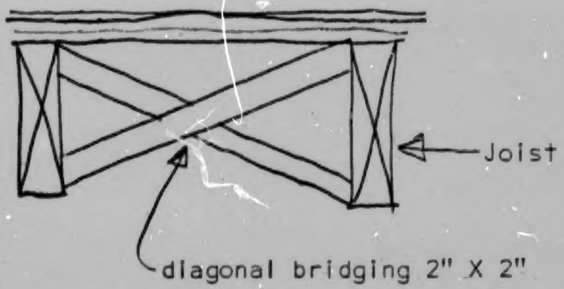
The area of joist support is known as the ______________________________

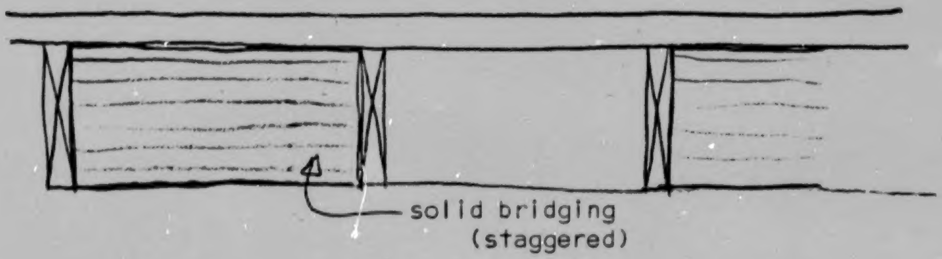
Joists as well as deflecting with the imposition of load also have a tendency to overturn.

This buckling causes an apparent increase in deflection and results in springiness in the surface.

To counteract this effect members known as bridging are inserted between the joists.

Bridging may be diagonal or solid.


Joist
diagonal bridging 2" X 2"


solid bridging
(staggered)

---

a) ________________ is required to counteract buckling

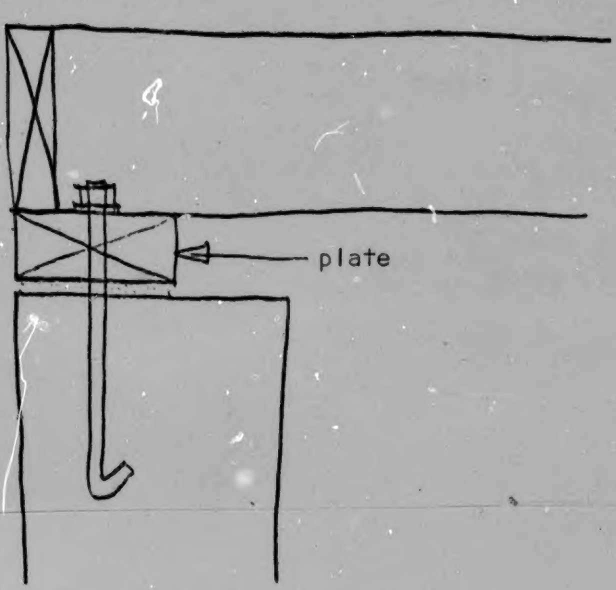
b) The two methods are known as ________________ and ____________________

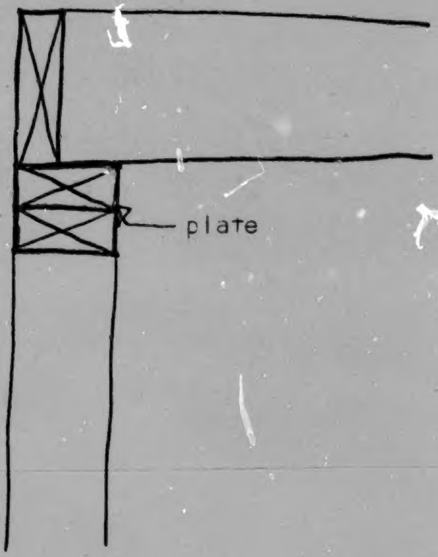
a. Bridging

b. solid bridging, diagonal bridging

Bridging is located at half span or at 8'0" o.c. across the span, and at ends of joists at their bearing.

The joist does not bear directly upon its final support. In order to provide a satisfactorily level bearing which is nailable, a member known as a plate is introduced beneath it mechanically connected to bearing surface.





a. Bridging is required at ______ at ____________________ and at ____________________

b. Between the joist and the bearing surface a ____________________ is located.

a. Bridging is required at 8' 0" o.c. at half span and at ends of joists at their bearing.
If you did not get the answers above turn to p. 11

b. Between the joist and the bearing surface a plate is located.

If you did not get this answer turn to page 13.

In the case of a concrete wall, it is neccessary either to embed the plate in cement mortar or on a prepared surface, with the interface caulked.

This is neccessary to ensure that

a. the plate is level.

b. an airtight joint is made.

(Check correct answer.)

Both answers are correct!

The plate must be both level and must have as airtight a connection as possible.

In order to prevent rotting of plates, they should be treated with preservative.

To ensure that the structure cannot be blown or moved from its location on the foundation wall it must be fastened down with an anchor bolt.

Anchor bolts must be provided at at least 8'0" o.c. must be a mimimum of 1/2" dia., and embedded in concrete at least 4", hooked to prevent with drawal.

For what purpose is an anchor bolt used?

a. To prevent structure from shipping off supports.
b. To locate structure to supports
c. To hold structure down

(Check one)

If you checked c. turn to page 20

If you checked a. or b. turn to page 16

c. To hold structure down, against the effects of wind, and in fact it also fulfils the needs of b. and c.

Preservative treatment of wood is essential where it is directly in contact with concrete, due to the fact that moisture can be held between the two materials, thereby providing ideal conditions for the growth of fungi.

Preservatives are actually compounds poisonous to fungi. (for a full discussion of fungi refer to appendix)

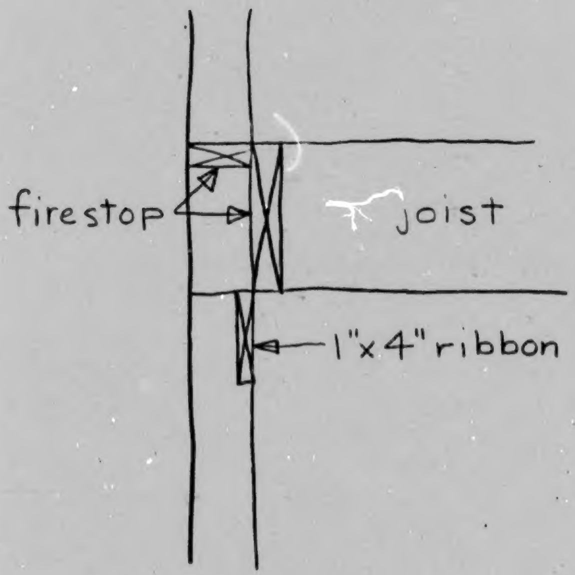
Obviously between roof and supports, there must be a support member or plane to transmit the load.

This can take many forms. For our present purposes we will consider the light wood framing system. There are generally two broad classifications of light wood frame. The Platform frame and the Balloon frame.

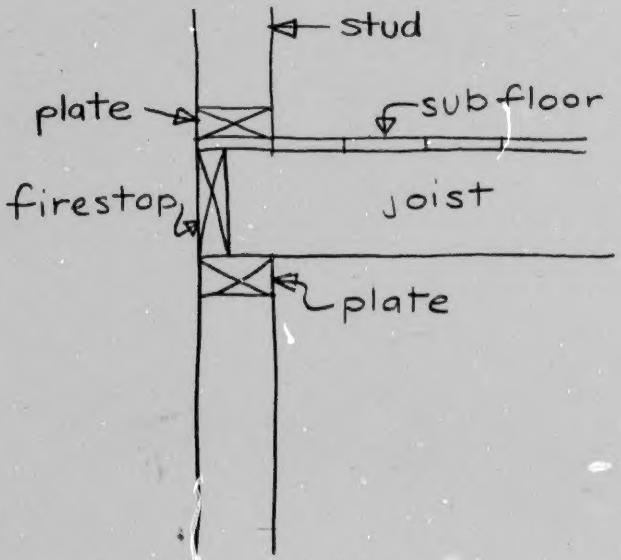
The essential difference between the two lies in the method of locating floors.

In Platform frame, the studs are storey height, the floor joists being located on top of the joists supported on the stud frame, to provide a working platform for the next construction sequence.

In Balloon frame the studs are carried the full height of the building, and the floors are connected to them subsequently.



Balloon frame



Platform frame

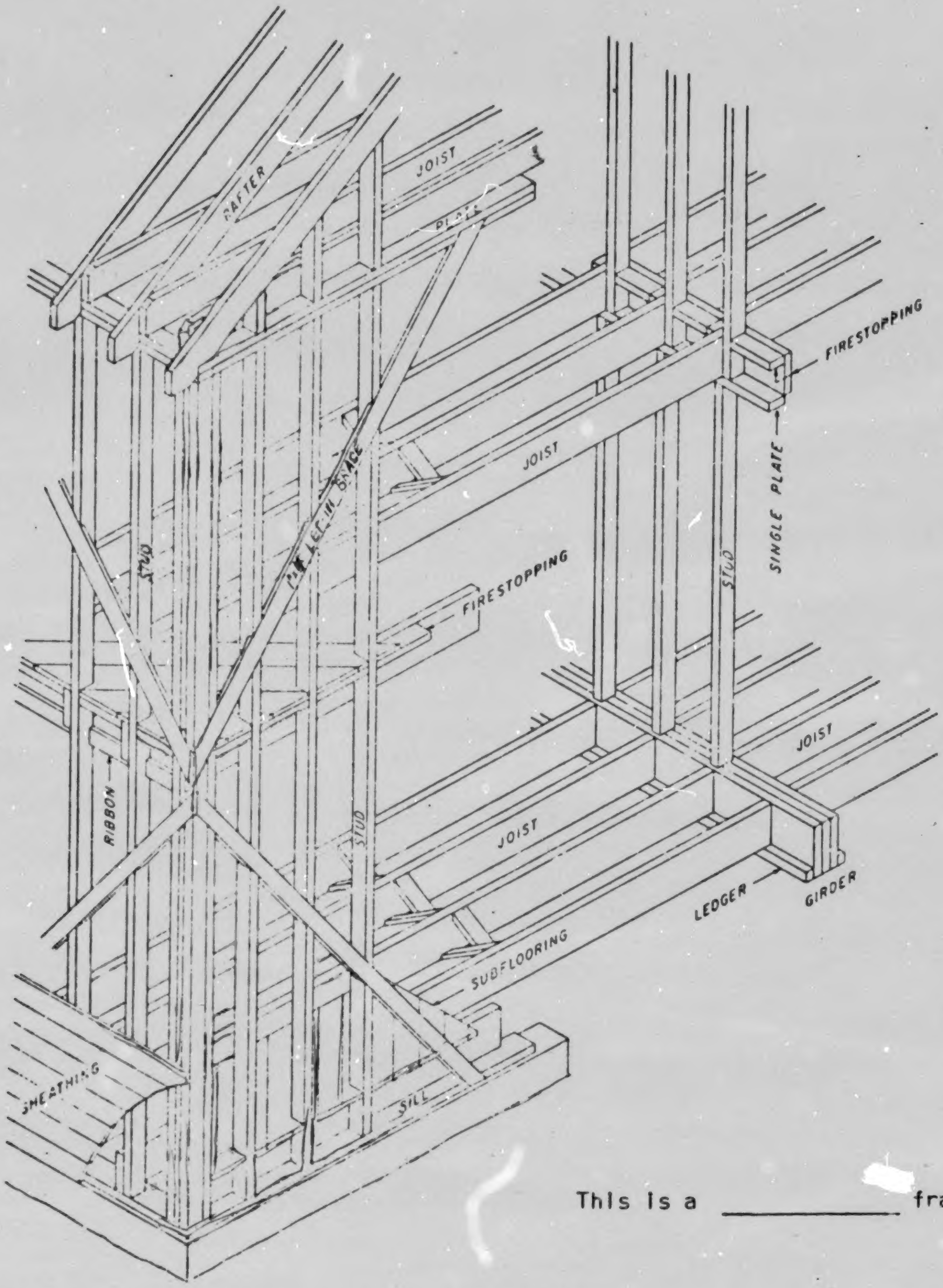
Studs are commonly nominal 2" X 4", that is, they are not the full size stated. Up until recently the actual size of a 2" X 4" was 1 5/8" X 3 5/8", as a result of setting the saw blades at the mill at the nominal centres. Now however sizing has been rationalized so that a 2" X 4" is now 1 1/2" X 3 1/2". Remember that all lumber sizes are nominal e.g. 2" X 10" nominal is 1 1/2" X 9 1/2" actual; 3" X 12" nominal is 2 1/2" X 11 1/2" actual, and so on.

The basic difference between the two major types of light wood frame construction is that in a) ________________ frame the studs are continous through the height of the building whereas in b) ________________ frame, the sub floor acts as a surface upon which subsequent operation can be carried out.

a. balloon

b. platform

Study the sketch below and try to visualize the parts, and their purpose.


RAFTER
JOIST
PLATE
FIRESTOPPING
JOIST
SINGLE PLATE
STUD
LET-IN BRACE
STUD
FIRESTOPPING
RIBBON
STUD
JOIST
JOIST
LEDGER
GIRDER
SUBFLOORING
SHEATHING
SILL

This is a ____________ frame.

Balloon Frame

Sill Plate or Plate a horizontal member interposed between studs and the support.

Joist a horizontal load bearing member.

Stud vertical load carrying member usually placed at 16" or 24" o.c.

Ribbon the horizontal member used as part location and part support for second and above floors in balloon frame.

Brace a diagonal member used to provide resistance to lateral movement.

Bridging member used to reduce effective length of supports and so rigidify the structure.

Firestopping a member minimum 2" nominal thick to reduce the rate of transfer of flame between floors.

Sheathing a thin material applied to the outside of a framed structure to make it rigid.

Sub flooring the rough (frequently diagonal) floor laid immediately on top of joists.

Girder or built up beam A composite member used to reduce span and therefore, size of joists.

Ledger a member attached to the side of a built up beam to enable the beam to be raised in relation to the floor beneath.

Advantages of Balloon frame: a) Rigidity over entire structure

b) Elimination of settlement variations.

From the preceding pages you should now understand the overall concept of the Balloon frame.

Construct a model at a scale of 3/4" = 1'0" of a corner of a typical balloon frame.

Name all the parts. The model should be extensive enough that additional aspects may be explored later, such as door & window openings and internal partitions, etc.

Produce a sketch of your model in axonometric projectior to a scale of your own choosing.

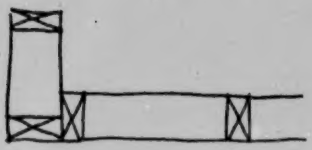
Turn to page 27 before carrying out this task.

You have no doubt realized that there are some apsects which you do not understand.

How do you construct the corners?

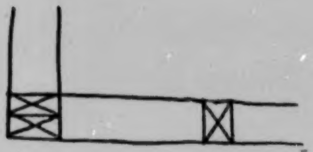
Plan

like this?



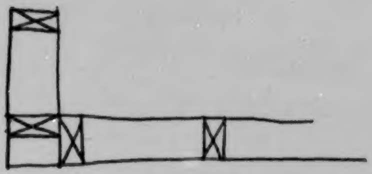
A

like this?



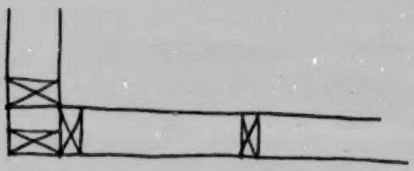
B

like this?



C

or like this?



D

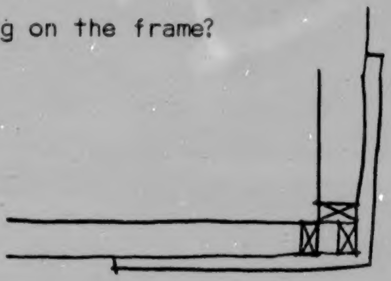
Check one.

'D' is the preferred method of constructing the corner. It provides the greatest rigidity with the minimum material, while providing full nailing capability on both inside and outside corners.

Note that none of the other examples provide this advantage.

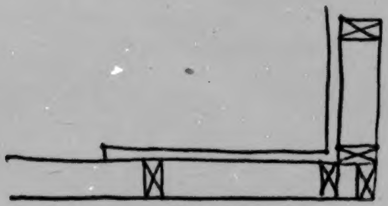
Do you know how to place your diagonal bracing on the frame?

like this?



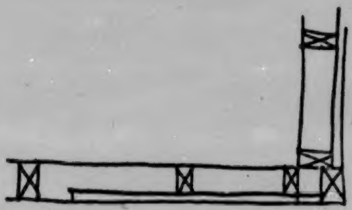
A

like this?



B

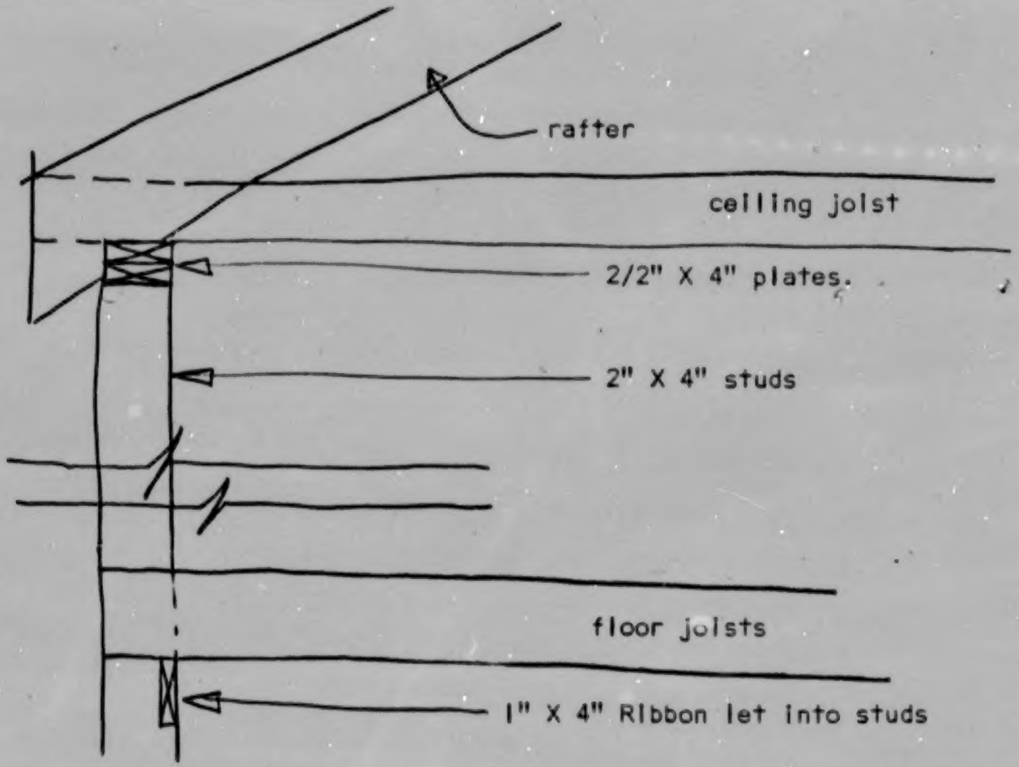
or like this?



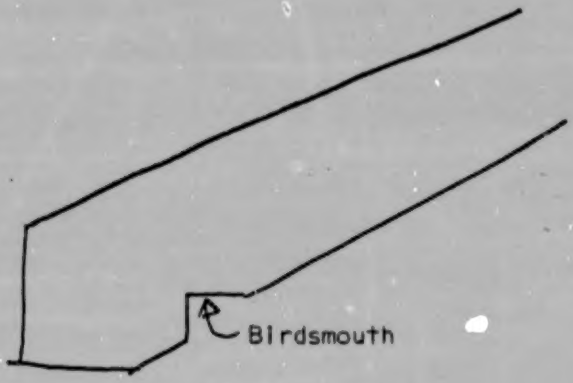
C

Of the alternatives presented only 'C' is appropriate because otherwise the sheathing or interior finish would have to be cut around the diagonal brace, at the expense of much increased labour and wastage of material.

Sometimes permanent bracing is not provided, the sheathing providing permanent lateral restraint. In this case temporary studs are removed just prior to sheathing installation. This is not however, considered to be best practice.


rafter
ceiling joist
2/2" X 4" plates.
2" X 4" studs
floor joists
1" X 4" Ribbon let into studs

In order to connect the rafters and ceiling joists to the frame they must be cut to provide a good bearing. This is known as notching or bird mouthing.


Birdsmouth

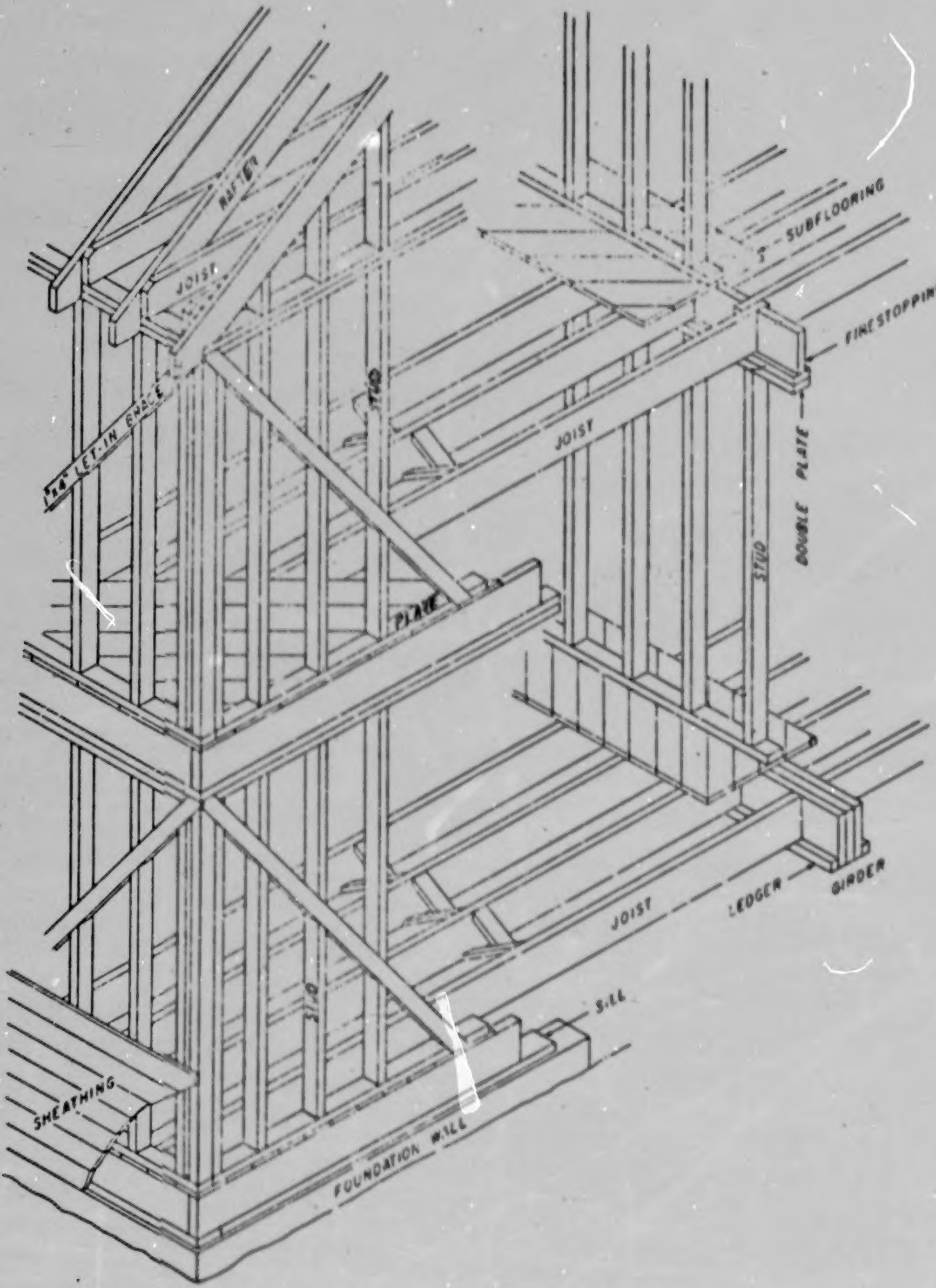
What is the purpose and what is a "ribbon"?

What are the advantages of Balloon Framing?

1) The Ribbon is the member used to support and locate 2nd floor joists in Balloon frame construction.

2) The advantages of Balloon frame construction are its rigidity and the equalization of settlement. As a result, it is the preferred form of construction where brick or stone veneer is to be used in the construction system.

Study this sketch


RAFTER
JOIST
STUD
1x4" LET-IN BRACE
PLATE
SUBFLOORING
FIRESTOPPING
JOIST
DOUBLE PLATE
STUD
STUD
JOIST
LEDGER
GIRDER
SILL
SHEATHING
FOUNDATION WALL

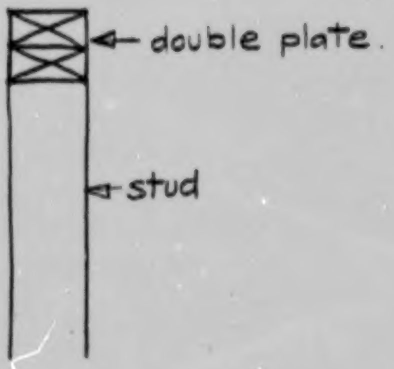
This a ______________________ frame.

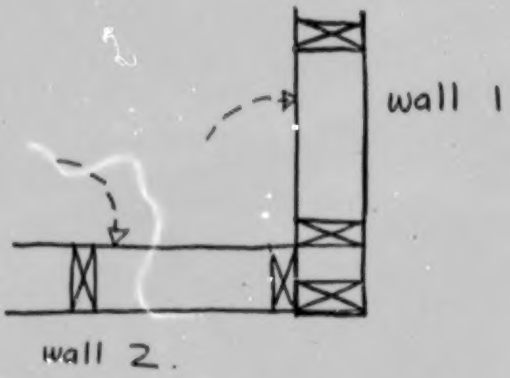
Platform Frame

The Platform frame is easier & faster to construct than the Balloon frame. It does not require lumber in the lengths essential for other construction methods, and it lends itself to a form of prefabrication.

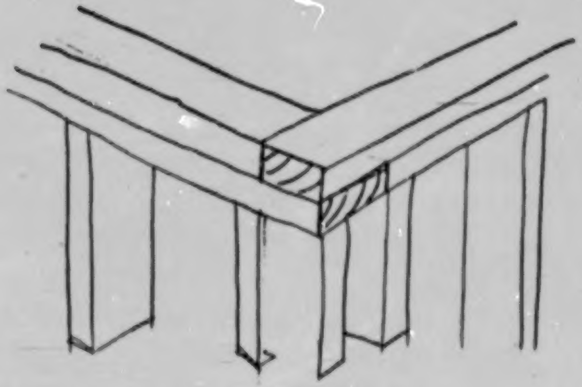
As Balloon frame, the platform frame commences with a sill plate, but the studs do not rise from this plate. All studs can be precut to a standard length. Joists and firestopping are placed, and upon this is constructed the sub floor. This now acts as a working platform for the storey under construction.

Walls are commonly prefabbed on the platform, and tilted up into position.





The double plate is a neccessity because of this form of construction they must cross link at the corners.

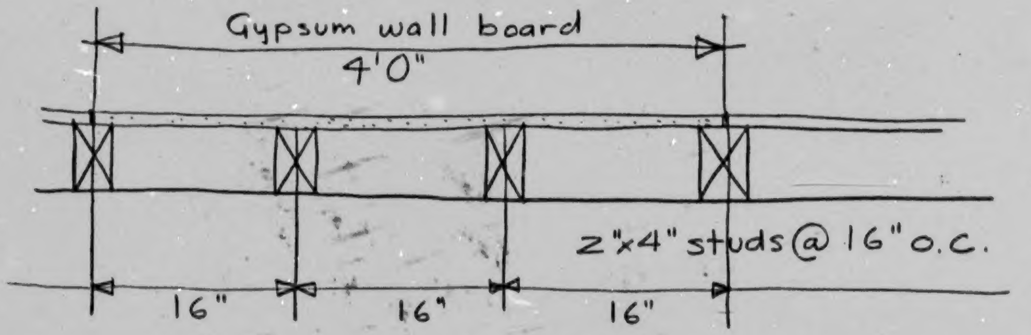


The load carrying components in framed constructions are known as
a) studs
b) joists

(check one)

If you checked (a) turn to page 36.
If you checked (b) turn to page 6.

Studs are the component members of a frame wall. They are usually placed at 16" o.c. although sometimes they can be used at 18" o.c. or 24" o.c. 16" o.c.; however, is the preferred spacing, mainly because most construction materials applied to them have dimensions of 4'0' X 8'0", and so edges of the material always occur on a nailable backing.



For instance, Gypsum wall board, plywood, plastic laminates all come in the standard size of 4' X 8'

Studs are commonly placed 16" o.c. because ____________________

____

____

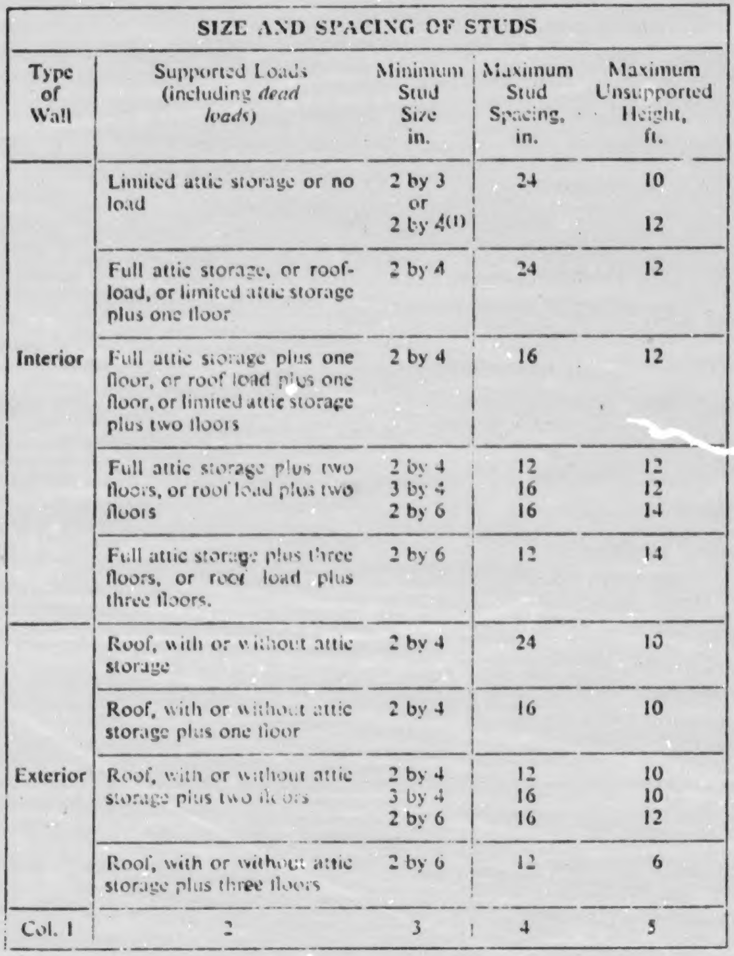
____

____

One of the reasons that studs are placed 16"o.c. is because of the standard sizes of sheet materials.

However, as well, it should be understood that loading must be taken into account when sizing and placing studs within a frame wall or partition.

Loading can be simply assessed by referring to the appropriate codes such as that reproduced frame the 1970 NBC below



SIZE AND SPACING OF STUDS

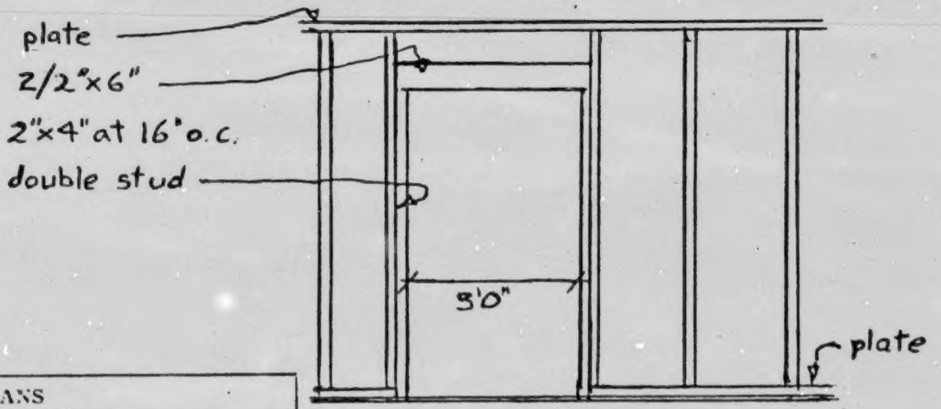
Type of Wall	Supported Loads (including *dead loads*)	Minimum Stud Size in.	Maximum Stud Spacing, in.	Maximum Unsupported Height, ft.
Interior	Limited attic storage or no load	2 by 3 or 2 by 4(1)	24	10 12
	Full attic storage, or roof-load, or limited attic storage plus one floor	2 by 4	24	12
	Full attic storage plus one floor, or roof load plus one floor, or limited attic storage plus two floors	2 by 4	16	12
	Full attic storage plus two floors, or roof load plus two floors	2 by 4 3 by 4 2 by 6	12 16 16	12 12 14
	Full attic storage plus three floors, or roof load plus three floors.	2 by 6	12	14
Exterior	Roof, with or without attic storage	2 by 4	24	10
	Roof, with or without attic storage plus one floor	2 by 4	16	10
	Roof, with or without attic storage plus two floors	2 by 4 3 by 4 2 by 6	12 16 16	10 10 12
	Roof, with or without attic storage plus three floors	2 by 6	12	6
Col. 1	2	3	4	5

Or they may be calculated.

Openings must be provided for both ~~in~~ [illegible] external and internal walls; for windows and doors.

What ever the opening, a means must be found to carry the loads so that the area of support removed from the walls can be taken care of. If one did not transmit the load so that load was applied on the windows or doors, the members would either deflect so that these components would be inoperable or damaged, or in severe cases of overload, collapse could occur.

In order to spread the load over an opening, a device known as a lintol is used.



The sketch illustrates a typical opening for a door in an internal partition on the lower floor in a two storey structure. Again, use can be made of tables as here, or, where the requirements are outside, the table may be calculated.

An opening in a single storey building interior stud wall is required. The opening will need to be 6'0" wide. What is the minimum size of lintol required? a) 2/2" X 6 b) 4" X 6" c) 2" X 12" d) 4" X 12"

2. 4" X 8" f 2/2" X 8" g 2" X 6"
Check applicable size

WOOD LINTEL SPANS

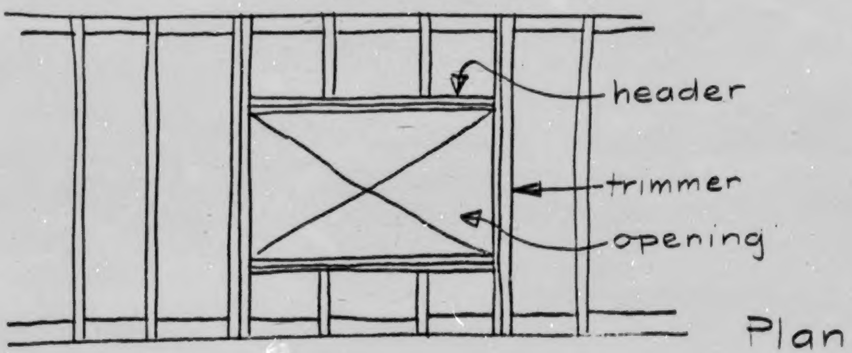
Location of Lintels	Supported Loads Including *Dead Loads* and Ceiling	Nominal Depth of Lintels, in.	Maximum Allowable Spans, ft. — in.
Interior Walls	Limited attic storage	4	4 — 0
		6	6 — 0
		8	8 — 0
		10	10 — 0
		12	12 — 6
	Full attic storage, or roof load, or limited attic storage plus one floor	4	2 — 0
		6	3 — 0
		8	4 — 0
		10	5 — 0
		12	6 — 0
	Full attic storage plus one floor, or roof load plus one floor, or limited attic storage plus two or three floors	4	—
		6	2 — 6
		8	3 — 0
		10	4 — 0
		12	5 — 0
	Full attic storage plus two or three floors, or roof load plus two or three floors	4	—
		6	2 — 0
		8	3 — 0
		10	3 — 6
		12	4 — 0
Exterior Walls	Roof, with or without attic storage	4	4 — 0
		6	6 — 0
		8	8 — 0
		10	10 — 0
		12	12 — 0
	Roof, with or without attic storage plus one floor	4	2 — 0
		6	5 — 0
		8	7 — 0
		10	8 — 0
		12	9 — 0
	Roof with or without attic storage plus two or three floors	4	2 — 0
		6	4 — 0
		8	6 — 0
		10	7 — 0
		12	8 — 0
Column 1	2	3	4

If you checked a) or b) read on, if you checked any others, turn back to page 39 and see if you can see where you went wrong.

Openings are not only required in walls. Frequently there is a need to provide openings in floors and roofs to permit the penetration of stairs, flues, elevators and so on.

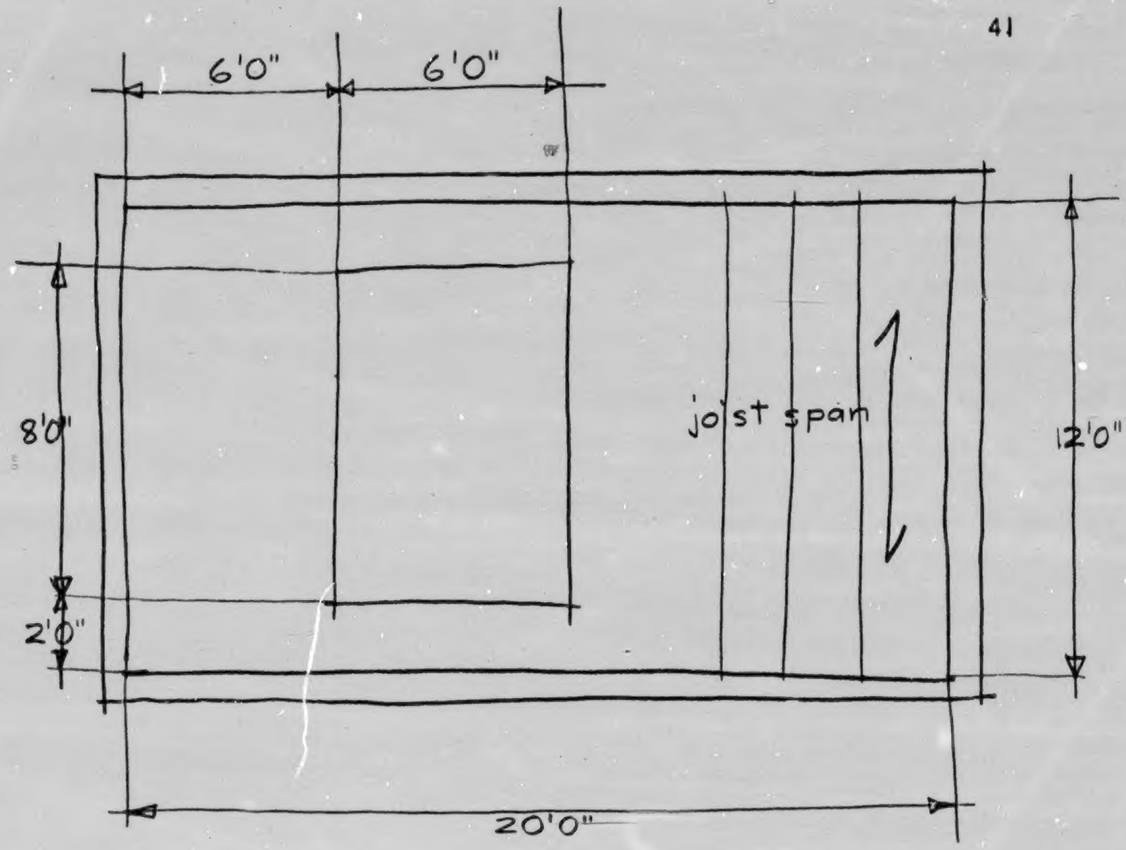
As it is obvious that the provision of an opening greater in size than the spacing of the structural members weakens the construction, steps must be taken to restore adequate strength to the areas affected.

This is accomplished by the introduction of headers across the span and trimmers parallel with the span.



For a span between 4'0 and 10' 8" headers should be doubled. Trimmers, too, must be doubled when the length of header is between 2' 8" and 6'8" in length.

Below these spans, single headers and trimmers can be used Above these spans their size must be calculated.


6'0"
6'0"
8'0"
2'0"
joist span
12'0"
20'0"

The plan above indicates the extent of a floor to be spanned. Sketch on the location and size of joists trimmers and headers required. Wood species Douglas Fir Standard grade.

Joists - 2" X 8", 16" o.c.

Headers - 2/2" X 8"

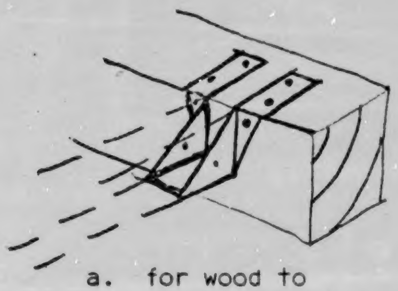
Trimmers - 2/2" X 8"

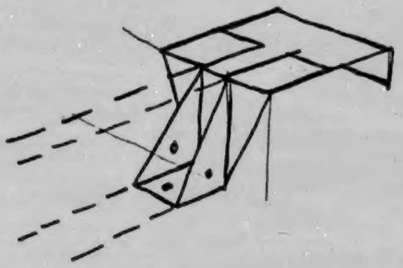
If you did not get this result, turn back to p. 41

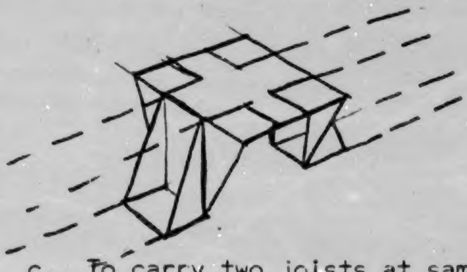
Its fairly obvious that when connecting these members together it would be advantageous if the tops of all members were level. To achieve this they can either be nailed together or, preferably, a joist hanger can be used. The problem with nailing is that one is forced to nail into end grain, and doing so can cause the wood to split, resulting in loss of strength, and additionally, nails driven into end grain are too easily withdrawn, resulting frequently in 'creaking' of the structure.

Joist hangers are used for a variety of connections not only for connecting headers to trimmers. They can be used to connect joists to wood beams, steel beams and concrete or masonry walls, to mention only a few of their applications.

The joist hangers is usually constructed of galvanised sheet steel, bent to shape


a. for wood to connect above, below, or level with beam.


b. for brick, tile concrete wall or steel beams.


c. To carry two joists at same position over steel beam, concrete wall or masonry wall.

A joist hanger is used to connect joists or headers to

a. b. c.

Give three examples.

A joist hanger is used to connect joists or headers to

a. wood or steel beams
b. concrete or masonry walls

c. wood trimmers

If you are not sure of your selection of answers to this question, turn back to page 42.

More often than not it will be found that floor joists will be required to span distances in excess of their capacity. In this event the effective span must be reduced by the provision of additional bearing members. These may be either beams or walls.

Beams may be solid wood, built up wood, laminated wood or steel beams.

Walls may be wood stud, concrete or masonry.

The table reproduced below indicates, sizes of built up wood beams to be used in various conditions.

BUILT-UP WOOD BEAMS IN BASEMENTS, CELLARS AND CRAWL SPACES, TWO-STOREY DWELLINGS

Species	Grade	Supported Joist Length (2, 3)	Size of built up beam, inches											
			3-2 x 8		4-2 x 8		3-2 x 10		4-2 x 10		3-2 x 12		4-2 x 12	
		ft	ft	in.	ft	in.	ft	in.	ft	in.	ft	in.	ft	in.
Douglas Fir Western Larch Pacific Coast Hemlock	Construction	8	9	6	10	11	12	0	13	10	14	6	16	9
		10	8	6	9	9	10	9	12	5	13	0	15	0
		12	7	8	8	11	9	8	11	4	11	8	13	8
		14	6	9	8	3	8	6	10	6	10	4	12	6
		16	6	0	7	7	7	8	9	8	9	3	11	8
	Standard	8	8	6	9	9	10	9	12	5	13	0	15	0
		10	7	5	8	9	9	4	11	1	11	4	13	5
		12	6	4	8	0	8	1	10	1	9	9	12	2
		14	5	8	7	1	7	2	9	0	8	8	10	10
		16	5	1	6	4	6	5	8	0	7	9	9	9
Pacific Coast Yellow Cedar Eastern Larch Jack Pine	No. 1 (Construction)	8	7	11	9	4	10	0	11	10	12	1	14	4
		10	6	7	8	4	8	4	10	6	10	0	12	9
		12	5	8	7	2	7	2	9	0	8	8	10	11
		14	5	0	6	3	6	4	8	0	7	9	9	8
		16	4	7	5	8	5	9	7	2	7	0	8	8
	No. 2 (Standard)	8	6	4	7	4	8	4	9	8	10	9	12	5
		10	5	8	6	7	7	6	8	8	9	7	11	1
		12	5	2	6	0	6	10	7	11	8	8	10	1
		14	4	10	5	6	6	4	7	4	7	9	9	4
		16	4	6	5	2	5	9	6	10	7	0	8	8
Fir (Amabilis and Grandis) Balsam Fir Eastern Hemlock Pine (Lodgepole and Ponderosa) Spruce (all species)	No. 1 (Construction)	8	7	6	8	8	9	6	11	0	11	6	13	4
		10	6	3	7	9	7	11	9	10	9	7	11	11
		12	5	5	6	10	6	10	8	8	8	4	10	5
		14	4	10	6	0	6	1	7	8	7	5	9	3
		16	4	4	5	5	5	6	6	10	6	8	8	4
	No. 2 (Standard)	8	5	11	6	10	7	9	9	0	10	0	11	6
		10	5	3	6	1	6	11	8	0	8	11	10	4
		12	4	10	5	7	6	4	7	4	8	2	9	5
		14	4	6	5	2	5	10	6	9	7	5	8	9
		16	4	2	4	10	5	6	6	4	6	8	8	2
Western Red Cedar Red Pine Pine (Eastern and Western White) Poplar (Aspen, Largetooth Aspen, and Balsam Poplar)	No. 1 (Construction) (No. 1 Dimension)	8	6	4	7	4	8	6	9	10	10	6	12	6
		10	5	8	6	7	7	3	8	9	8	9	11	0
		12	5	0	6	0	6	3	7	10	7	7	9	6
		14	4	5	5	6	5	7	7	0	6	10	8	5
		16	4	0	4	11	5	1	6	3	6	2	7	7
	No. 2 (Standard) (No. 2 Dimension)	8	4	11	5	8	6	9	7	9	8	6	9	10
		10	4	4	5	1	6	0	6	11	7	8	8	10
		12	4	0	4	7	5	6	6	4	7	0	8	1
		14	3	8	4	3	5	1	5	11	6	5	7	6
		16	3	6	4	0	4	9	5	8	6	0	7	0

A floor consisting of 2" X 10" joists @ 16"o.c. is required to span 20'0". Is it possible to span this distance without additional support?
a. Yes b. No (Check I)

If no, is your answer, and you have decided that a beam is required, using table on p.44, what is its size?

The beam span is limited to 12'0"c.c., and the lumber to be used is construction grade spruce.

a. 4-2" X 10" I beam required at mid span.

b. 4-2" X 12" I beam required at mid span.

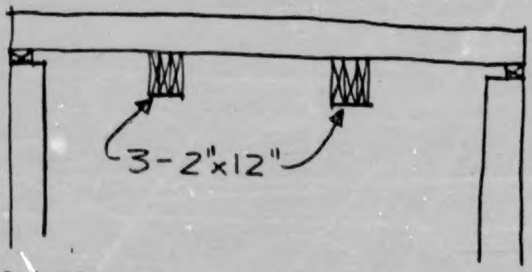
c. 3-2" X 12" 2 beams required at 1/3 span.

d. 3-2-10" 2 beams required at 1/3 span.
check your solution.

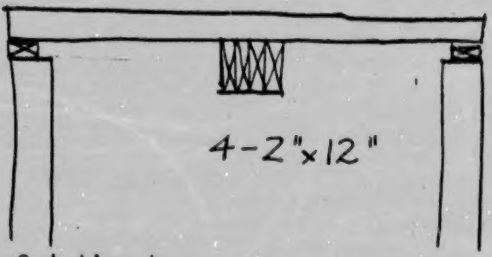
Sketch your solution.

Unless the depth of the joist is increased and the spacing reduced a beam or some form of intermediate support is neccessary.

The choice is between b and c, both of which solutions are adequate.



Solution c



Solution b

If you checked any other solution review pages 44, 45.

Now it becomes obvious that the beams carrying the floor are limited in length, and it is frequently necessary to provide space in excess of the beam spans available Again, use can be made of point supports - that is columns of wood, steel, masonry or concrete, or of continuous supports at right angles to the beams, that is loadbearing walls of wood masonry or concrete.

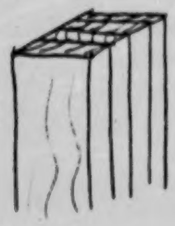
In small scale construction (up to two stories) two types of columns support are used most frequently. The solid or built up wood post or the steel jack post.

The size of columns should normally be calculated, but for small buildings there are minimum requirements.

Wood posts

The diameter of a circular or width of a rectangular wood column must always be as great as the width of the beam it supports. Unless calculations prove otherwise, the minimum size of wood columns are 8" diameter for round columns, 6" X 6" for rectangular ones. They can be solid, glued laminated or built up. Glued laminated columns are subject to compliance with CSA 0177 which is a qualification code for Manufactures of this kind of assembly. See appendix.

Built up columns consist of a series of strips of wood the full length of the final column, the same width as the finished column and 2" thick

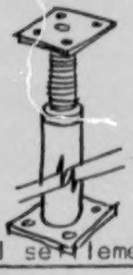


Built up 8" X 8" column
Consisting of 4-2" X 8" pieces of wood.

Steel Columns or posts

Steel pipe columns may be used in locations as for wood in which case they must be a minimum of 2 7/8" outside diameter with a wall thickness of 3/16" and be provided with 1/4" thick 4" X 4" steel plates at each end.

A now acceptable variation on the steel column, much favoured by contractors is the adjustable steel jack post. This consists of a heavy gauge tube into which is fitted a boss containing a heavy coarse pitched threaded section of hardened steel which can be adjusted before and after installation for length It, too, has 4" X 4" X 1/4" plates welded to each end.



This provides a means to counter the effects of differential settlement

Whatever type of support is used, there must be secure fastenings provided between all members to prevent lateral movement.

A built up beam consisting of 3-2" X 8" construction grade Douglas Fir carries a floor 20'0" X 30'.

How many wood posts at what spacing are required?________________

a. 3-6" X 6" posts at 7'6" o.c.

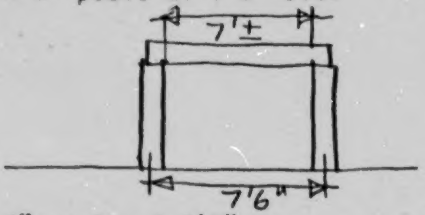
b. 2-6" X 6" posts at 6'8" o.c.

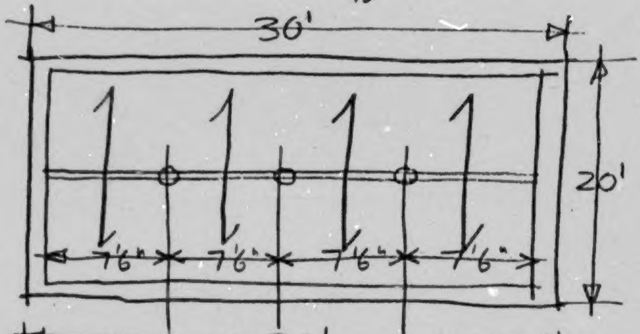
c. 2-6" X 6" posts at 10' 0" o.c.

d. 1-6" X 6" post at mid span.

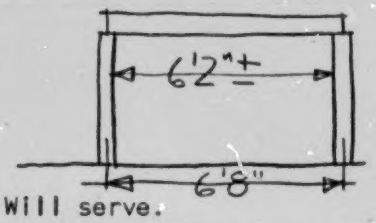
Check I and sketch your solution.

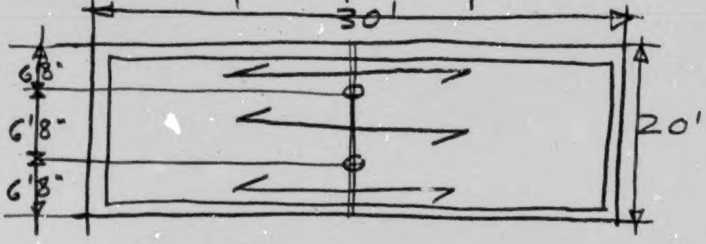
Both a. 3-6" X 6" posts at 7'6" o.c.





and b. 2-6" X 6" posts at 6'8" o.c.





Will serve.

Note that in each case, the actual span of the beam is less than the o.c. spacing of the posts.

Solution c. exceeds the safe beam span,
and the beam would therefore have to be increased in size to 4-2" X 8"

Solution D. Also exceeds the safe beam span and would require a beam size increase to either 3-2" X 12" or 4-2" X 10"

The decision to place the beam on the long or short axis of the building is influenced by many factors - length, size and cost of available lumber, space requirements of spaces at the lower level and so on. Very simply, the resultant floors could be compared for quantity of wood.

Estimate the sizes of joist required in each of solutions a. b. c. above, using construction grade Douglas Fir.

Solution a 2" X 6" @ 16" o.c.
Solution b 2" X 8" @ 12" o.c.
Solution c 2" X 6" @ 16" o.c.
Solution d 2" X 8" @ 12" o.c.

A board foot of wood of any given grade and species will not vary significantly to size of finished member.

So a direct comparison between choices can be made.

A board foot is a piece of lumber 12" wide 12" long and 1" thick. So that 12' X 12" X 1" nominal board is 12 bd. ft. and 12' X 2" X 4" nominal stud is 8 bd. ft. For comparison anly solution a. would require 26 joists, each 20' X 2" X 6", i.e., 520 bd. ft. for joists plus 30 X 3 X 2" X 8" = 120 bd.ft. for a total of 640 bd.ft.

Solution b. would require 22 joists each 30' X 2" X 8" i.e. 880 bd.ft. for joists plus 20 X 3 X 2" X 8" = 80 bd.ft. for a total 960 bd.ft.

So it can be seen that quite obviously solution a is more economical than solution b because it uses less material. However, this does not explore the entire situation as b. requires fewer posts, and leaves the area beneath the floor clearer, and depending upon what factors are of greatest importance, the final decision may favour another solution.

Assuming that posts in a. and b. are 8'0" long, how many bd. ft. of lumber is involved?

a. ______________________________ bd. ft.

b. ______________________________ bd. ft.

a. 3 - 6" X 6" posts 8' long = 72 bd. ft.

b. 2 - 6" X 6" posts 8' long - 48 bd. ft.

All members which transmit loads to the ground require footings. These are usually of concrete, often unreinforced, and simply spread the load so that the ground bearing pressure is not exceeded.

In fact, it is usually required that loads on the ground are limited to a maximum of 1/3 the ultimate ground bearing pressure. Most commonly, 3000 lbs/in^2 @ 28 days concrete is used for both strip and pad footings.

The table below indicates minimum footing sizes. Wood frame construction.

No. of floors supported	Minimum strip footing widths		Minimum area of Column footings spaced not more than 8'0" o.c. wood or steel
	Supporting Exterior walls	Supporting Interior Walls	
1 Wood	10 in.	8 in.	4 1/2 sq. ft.
2 Wood	14 in.	14 in.	8 sq. ft.
3 Wood	18 in.	20 in.	11 sq. ft.
1 Masonry Veneer	12 1/2"	8"	
2 Masonry Veneer	16 1/2"	14"	
3 Masonry Veneer	20 1/2"	20"	
1 Masonry	15"	13"	
2 Masonry	19"	19"	
3 Masonry	23"	25"	

A. The continuous support bearing on ground and carrying a wall is known as a (strip) (pad) footing.

B. The support member bearing on ground and carrying a column or post is known as a (strip) (pad) footing.

C. The ultimate ability of the ground to carry load is known as
spread load
ground bearing pressure
ultimate ground bearing pressure
footing load
allowable ground bearing pressure
(check appropriate description)

A. Strip footing

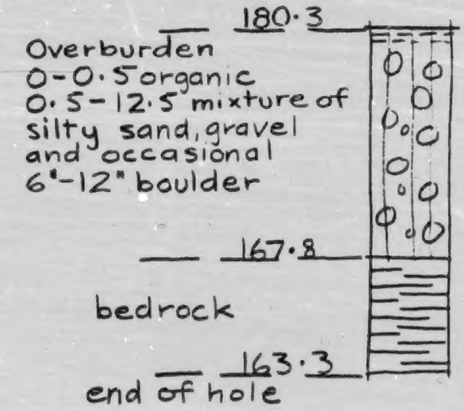
B. Pad footing

C. Ultimate ground bearing pressure.

The ground bearing pressure, or allowable ground bearing pressure is the load on the ground which should not be exceeded. This is usually 1/3 of the ultimate ground bearing pressure.

The soil conditions are normally derived from a soils or foundation analysis, carried out by specialists in this field. Testing normally consists of test pits, test borings and laboratory analysis.

Sketch of typical boring log.

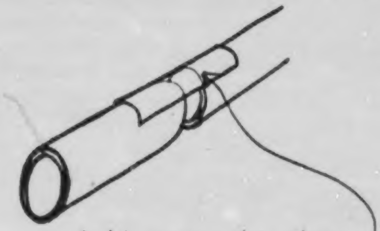

180·3
Overburden
0-0·5 organic
0·5-12·5 mixture of
silty sand, gravel
and occasional
6"-12" boulder
167·8
bedrock
163·3
end of hole

Drill hole No. 1

The tables on page 51 are for use only where it is known that no problems exist and the structure to be erected does not exceed 3 floors and basement.

The procedure outlined on Page 53 is recommended on all building projects which do not fall within the categories above. Mention was previously made of test pits. These are always of value as they allow visual interpretation of bearing materials and, more importantly, can give a very clear approximation of the ground water table. The ground water table which is never flat is the uppermost level of water in the ground. It varies normally and significanly from a maximum in late Winter/Early Spring to a minimum in late Summer/Fall. The presence of water in the ground is ignored only at considerable risk. As this water exerts pressure on sub structures, at the least it results in leaky and wet basements, and at the other end of the scale can actually float a building. As buildings are rarely designed as boats, the rise and fall can literally wreck the super structure. For this reason means are used to drain off water and thereby reduce pressure on foundations. This will usually consist of pipes, either perforated or with open joints laid around the perimeter and sometimes herring bone fashion under slabs. The pipes are then connected to a convenient drain, sewer or water course.

Perforated pipe



felt cover to stop ingress of soil.

Pipe laid with open joints

Footing drains are used to a) Drain off excess water

b) Prevent leaks in basements

c) Prevent Building from floating

d) Lower ground water table

Check one

Lower ground water table.

If you chose any but this answer refer back to page 54. Although footing drains achieve all these things described it is only as a consequence of lowering the ground water table. Footings do not have to be concrete, nor do they have to be strips or pads. They can be of many materials. Wood, masonry and steel have been used successfully for many years. Frequently Piles are used where support is not available at a convenient depth. Piles can be of precast concrete, poured in place concrete, steel, or wood. They may be end bearing or friction piles. They may be driven or bored.

Then there are Caissons and rafts.

A raft foundation is essentially a series of pad footings connected together to form a single slab. The implication of the name is most revealing, for in fact if the foundation is deep enough it can be designed to float - the weight of the entire building being equal to the weight of displaced soil.

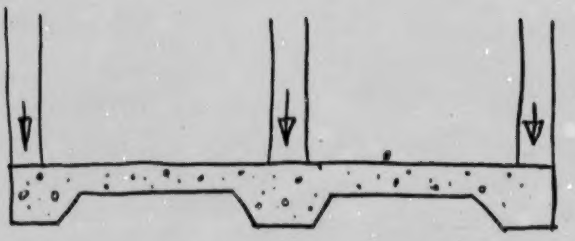
A caisson is actually an accessible shaft, usually belled at the bottom pressurized to resist collapse which permits inspection of the bearing surface and when filled becomes a column through which building loads can be transferred to bedrock or other suitable material.

As these kinds of foundations are beyond the present scope it is sufficient that you should be aware of the terms used to describe these items, and to know what each of them are.

A friction pile carries loads by transmitting imposed loads to the soil through frictions between its sides and the surrounding soil.

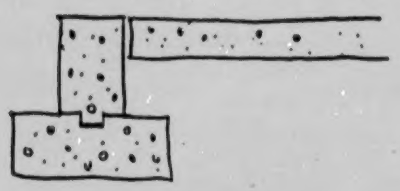
An end bearing pile carries loads by acting as a simple column, transmitting loads to the soil at its end.

A



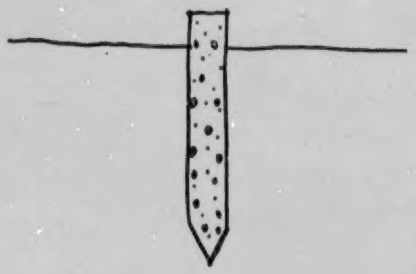
This is a (floating) (pad) (strip) foundation. (Check one).

B



This is a (pad) (raft) (strip) (floating) foundation (Check one)

C

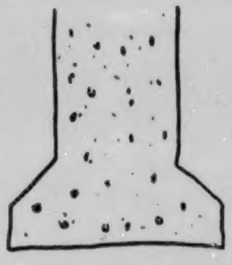


This is a (caisson) (bored pile) (driven pile) (friction pile) (end bearing pile) (Check one)

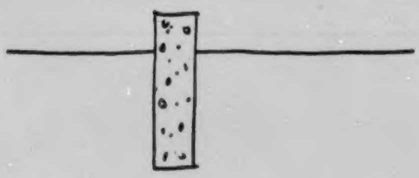
A. This is a raft foundation. Note that the concrete is continuous across the slab but is thickened where loads are supported. This type of footing must be reinforced with steel. It could be called a floating foundation but in fact it is not until the displaced soil is equivalent in weight to the total building. It is obviously not a pad or strip foundation. See page 51, 52, 53.

B. This is a strip foundation. Note that there are joints between footing, wall and slab. The joint between footing and wall is for convenience. The joint between floor and wall is essential.

C. This is a driven pile. It is not possible to say from such a sketch whether it is a friction pile or an end bearing pile, as this is much more a matter of design than of appearance. The appearance of bored piles and caisson are different however, a caisson often looking like this.



and a bored pile like this



The bored pile does not need a shoe, or pointed end.

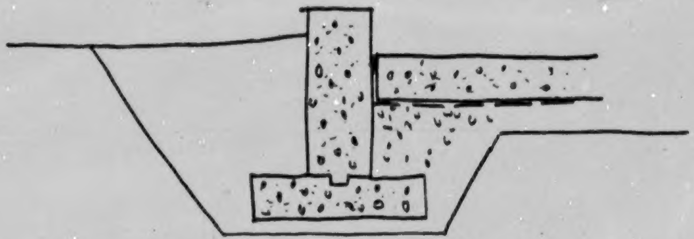
Although in small buildings of the kind discussed here there will not usually be any need to be concerned with expansion joints, that is joints which permit horizontal movement without overstressing components; there is need to consider movement as a result of settlement and differential expansion and contraction.

It is neccessary to understand and accept that all materials move for many reasons: moisture content and temperature are the root causes but combinations and consequences of these two plus the effects of mechanical strength and aging result in a broad basis for unwanted effects.

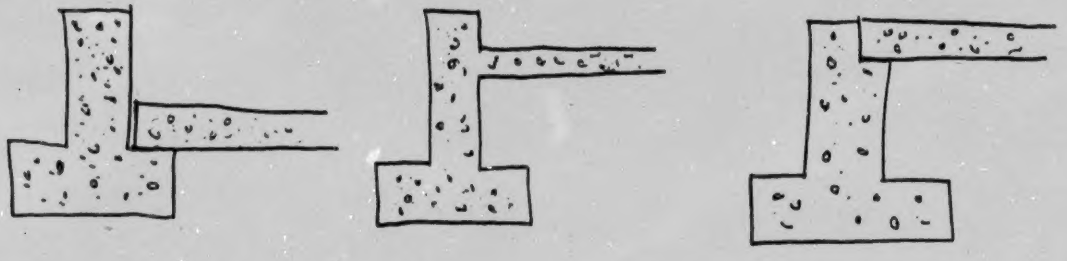
We will look at two types of movement only in detail:

Settlement and Differential expansion and contraction

Settlement results from the fact that if a great weight is placed upon the ground it will normally be compressed. Careful and thorough compaction of ground can reduce the effects of settlement to an almost negligable amount, but all buildings settle. Careful design can reduce the effects of settlement by ensuring that movement takes place at well defined locations.



The sketch above shows a typical section through a foundations wall and concrete floor slab. Both are unreinforced. Shrinkage of concrete tends to retract the floor slab from the wall, the greater load on the foundation wall has a tendency to cause a shearing or slipping action between the wall and floor. Details of the type above allow movement to take place without damaging either component. The sketches shown below do not permit movement and should be avoided.



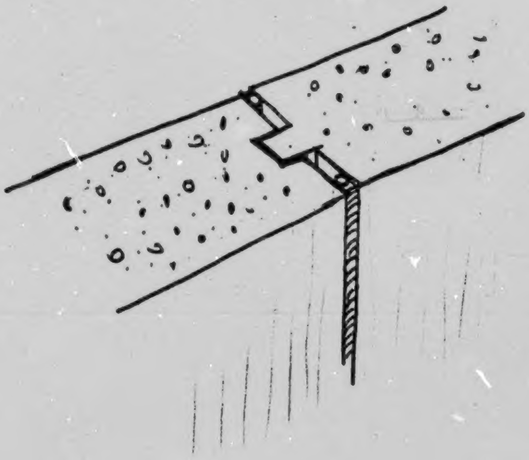
Movement of a building takes place a. vertically
b. horizontally
c. vertically and horizontally
d. in all directions

(check one)

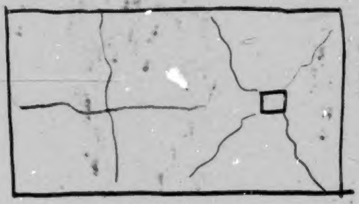
Movement takes place in all directions, but through careful design they can be taken care of with horizontal and vertical joint designs.

Inspect the basement of a typical residence. Prepare sketches of floors and walls showing locations and size of cracks. Write a report describing conditions, the reasons for their occurence and the ways in which the problems could have been prevented. Complete this assignment before proceeding further.

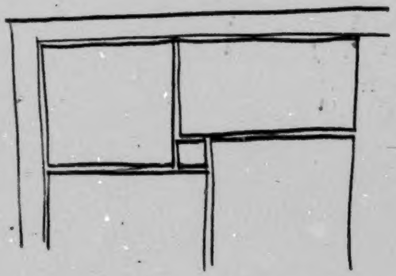
Cracks in unreinforced walls usually occur at openings and in a fairly regular pattern about 15'0" o.c. These are usually quite narrow - no more than 1/8" - greater size of cracks generally results from differential settlement, caused usually by unequal compaction of the ground beneath the footings. The former type of movement is caused by simple shrinkage of concrete. It can be minimized by careful compaction and curing of concrete and by reinforcing with steel. Despite these precautions, shrinkage will still occur. The best that can be done is to control the locations of the crack, and to allow for constant movement. This is done by constructing an expansion joint. The design of these joints can become very sophisticated but the principle is always the same: to separate the components into sizes which are stable, and to provide an impervious material between them which is elastic:



In floors it will be found that a fairly rectangular pattern of cracks at about 15'0"o.c. is formed, except that diagonal cracks form around columns, as shown below.



To control these cracks floors should be cast in bays between 10' and 15' square. The joints so formed are filled with a caulking compound. Around columns floors are cast thus:



So that each panel of concrete is free to move without affecting the adjoining component. This system makes it essential to pour concrete in checkerboard fashion, and this tends to be inconvenient. An alternative method of providing joints is to use a diamond saw. The entire slab is poured, and then, within seven days of the pour, the machine is used to cut it into bays. This cutting must go right through the slab. Frequently one will see apparent saw cuts, but if they do not extend far enough into the material they become useless decoration.

Concrete is a very common building material for many reasons, but its strength, durability and convenience are those which have the greatest appeal.

Concrete is a mixture of Portland cement, fine aggregate and coarse aggregate and water.

Portland cement - so called because of the similarity of appearance in colour and texture to Portland Stone - is made by heating a mixture of limestone and clay to a high temperature, and grinding this product to a fine powder together with a small quantity of gypsum.

There are several types of Portland Cement manufactured for a variety of purposes, all of which are described in detail in CSA A - 5. In general there is ordinary Portland Cement for most general construction purposes. Sulphate resisting concrete for use in situations where deterioration due to sulphate attack must be guarded against, and high early strength cement for use in situations where working loads must be applied before proper curing of standard cement had proceeded to the point where load applications could be safely contemplated.

Fine aggregates are particles of rock, sand, slag or other inert materials which will pass a 3/8" sieve, coarse aggregates are similar materials but ranging in size up 2 1/2" - the actual size used depending upon location and requirements of the component being produced.

Concrete is composed of (Sand and Cement) ________
(aggregate and cement)
(fine aggregate coarse aggregate and cement)
(cement water and aggregate)

Check one.

Concrete is composed of cement, water, and aggregate. The fineness of the aggregate will have direct affect upon the quantity of cement to be used, but the amount of water has been proved to be the major factor in determining the final strength of the concrete.

Concrete does not set as a result of water drying out, although naturally there is a large degree of evaporation of water. Concrete sets due to a chemical action known as 'hydration!' Typically, even in a dry mix, much more water is added to the ingredients than is required to hydrate the cement. The addition of water improves the workability of the material but seriously reduces its strength. The aim, therefore, is to produce a mix which is sufficiently workable with the minimum water content.

Visit construction lab and perform experiments under the guidance of the technician.
The amount of water to cement is the water/cement ratio.

The site test prior to placing is the slump test.

The more water, the greater the slump and vice versa. As well as affecting strength, the water cement ratio has an affect upon dimensional stability of concrete. As all the cement paste does is glue the particles of aggregate together, it should be obvious that if excess water exists initially, its evaporation will result in shrinkage and the development of voids, as hydration is completed long before evaporation has ceased.

In order to attain the ideal of a minimum water/cement ratio with an acceptable degree of workability chemical additives have been developed. These additives essentially effervesce, causing the formation of many air bubbles within the concrete. This is also known as "air entrained concrete". Concrete made in this way is less susceptible to frost action (the cells formed do not interconnect) and is far easier to place.

The following experiment must be undertaken in the Construction Lab.

Intent

To find the effect of water/cement ratio on bulk density, percentage porosity and compressive strength of cement mortars.

Theory

Water is added to cement to produce chemical change which causes the cement to set, and also to lubricate the aggregate particles so that they will slide over another and compact into a dense concrete. The water required for the chemical change is determined by the nature and quantity of the cement and must be sufficient for the chemical change to proceed to completion; the water required for workability depends upon the nature and grading of the aggregate and the method to be used for compaction. The water not chemically combined with the cement will evaporate as the concrete dries out, leaving voids, which reduce the density and mechanical strength. Maximum density and strength should be given by the use of the minimum quantity of water to give the necessary workability.

Method

1. Weigh out 200g amounts of Portland cement and 600g quantities of sand and measure mixing water to give water/cement ratios of (a) 0.45 (b) 0.55 (c) 0.65 (d) 0.75
2. Mix dry and then with water.
3. Place in oiled moulds in two layers and consolidate each layer by 25 strokes with rammer.
4. Identify each mix.
5. Store for 24 hours at 90 per cent R.H. and then immerse in water for 7 days.
6. Weigh.
7. Dry in oven at 105°C.
8. Weigh, calculate bulk density and percentage porosity.
9. Determine compressive strength.
10. Plot graphs indicating relationship between W/C ratio and % Porosity, W/C ratio and strength.

Report

Cube	Ratio	Volume	Bulk Density	% Porosity	Compressive Strength
A					
B					
C					
D					

1/67

FJE:bdr

The hardening of concrete is a result of

a. the evaporation of water

b. the entrapment of air within it

c. the combination of water with cement

(Check one)

The hardening of concrete is a result of the combination of water with cement or hydration. This chemical action produces heat which in large components requires cooling by special means. This is not a significant problem in small buildings. In order to produce satisfactory concrete it must be cured. Concrete is cured in warm weather by simply ensuring that there is not premature loss of water. In cold conditions, in addition to preventing loss of water, the material is heated, both during placement and for a period - usually seven days - thereafter. Freezing must be avoided at all costs. Frozen 3000# concrete has been known to reach compressive strengths of less than 600# at 28 days and this quite obviously spells danger.

In common with natural stone, which material it most closely resembles, concrete is a heavy material characterized by great compressive strength but poor tensile strength.

In order to improve its tensile strength metal is used as a reinforcement. Fortunately steel and concrete both exhibit almost the same coefficient of expansion and thus work extremely well together. Thus it is that steel in bar and mesh form is universally used for the purpose of reinforcing concrete. For the Architect one of the greatest advantages of concrete lie in its ability to assume practically any shape - it can be sprayed as well as placed. This is so much the case that it is sometimes referred to as a "plastic" material.

Because concrete is (strong) (weak) in compression and (weak) (strong) in tension steel is used to increase the (tensile) (compressive) strength of the composite material.

(delete the inappropriate words)

Concrete is strong in compression and weak in tension. Steel reinforcement is used to increase the tensile strength of the composite material.

The design of reinforced concrete members is covered in structures courses, and so this aspect is not discussed here. However, the production of steel is a part of construction. When embedded in concrete, sufficient cover must be provided over the reinforcement in order to protect it form corrosion. The amount of cover varies in accordance with the location and type of component. In footings there must be a minimum of 3" of concrete between steel and ground. Concrete exposed to the weather must have 2" cover for bars larger than #5 and 1 1/2" for bars #5 or smaller. Walls and slabs not exposed to weather require 3/4" concrete cover over reinforcement and beams and girders require 1 1/2" cover in the same situation. Column reinforcement must have 1 1/2" of cover or not less than 1 1/2" times the maximum size of coarse aggregate. The covers stated are minimum, they must be increased for fire protection purposes and in corrosive atmospheres or in extreme exposures.

Concrete cover is required over reinforcement to ____________________

a. Ensure bond

b. Protect it from effects of fire

c. Protect it from corrosion.

Concrete cover is required around reinforcement to protect it from corrosion.

Prepare sketch sections through a typical 2 storey framed structure

a. platform framed

b. balloon framed.

Show foundation, foundation walls and drainage, floor slabs, roof and window openings.

On page 28 the subject of sheathing was introduced. Review pages 22-29 before reading on.

Sheathing provides lateral restraint for frame wall and roof construction. It can take many forms. It can be diagonal or horizontal boarding, plywood, or other nailable sheet material.

The three most popular materials are wood boarding, plywood and particle board. The plaster or plasterboard interior skin also acts in the same way as sheathing applied to the outside of the frame, but it is rarely considered as such.

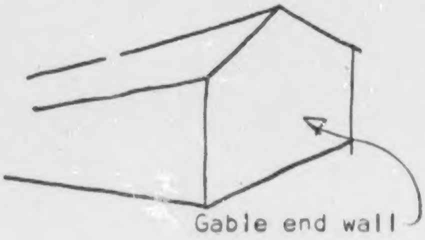
The sheathing must of neccessity be nailable in order that finishing materials may be attached to it.

The following table indicates the minimum sheathing thickness for various conditions in walls.

	Minimum Thickness	
Type of sheathing	Supports @ 16"o.c.	Supports @ 24"o.c.
Wood boarding	11/16"	11/16"
Insulating fibreboard	3/8"	7/16"
Gypsum board	3/8"	1/2"
Exterior type plywood	1/4"	5/16"
Particleboard	1/4"	5/16"

Although gypsum board and fibreboard are included, they cannot be used for the attachment of siding materials as they will not retain fasteners, such as nails or screws. They can be used in conjunction with veneer construction, where fasteners are connected to the structural system through the sheathing.

Sheathing is not essential in certain circumstances when exterior cladding does not require fastening between supports such as is the case with horizontal boarding or plywood sheathing may be omitted, but only if it does not affect lateral stability. For instance a gable end wall must be sheathed because it provides lateral stability. If lateral stability is provided by other means, such as bracing, the sheathing can be deleted.



An exterior wall consisting of 2" X 6" studs at 16" o.c. is to be clad with cedar shingles.

a. It does not require sheathing

b. It requires 11/16" boarding as sheathing

c. It requires 3/8" gypsum board as sheathing

d. It requires 15/16" exterior quality plywood as sheathing

Check the appropriate solutions.

An exterior wall consisting of 2" X 6" studs at 16" o.c. clad with cedar shingles requires backing and must be nailed between supports. It must therefore be sheathed. Gypsum board will not hold nails, and is therefore of no use. 15/16" exterior quality plywood is thicker than neccessary, though a good choice otherwise. 11/16" boarding fills the bill exactly, and is easier to nail.

Sheathing must be adequately nailed to studs. Boarding as above would require 2 two inch nails into each support if less than 8" wide and 3 two inch nails into each support if more than 8" wide.

The size and placing of nails is most important as too few or too small will not be sufficient to hold the structure together whereas too many or too big in extreme cases can split and damage materials and contribute to poor building performance.

Assuming that 5/16" plywood was used in the above example, how many and what size nails would be required?

See appendix for nailing tables.

Sheathing in this case would require 2" nails driven into supports 12"o.c. along intermediate supports and 6" o.c. along edges.

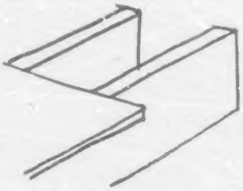
Contractors frequently prefer to use sheet materials for sheathing as it reduces labour and thereby cost of construction.

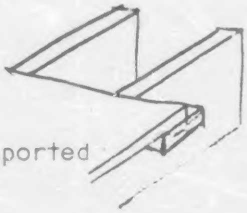
Having satisfactorily prepared the frame to receive the cladding, the cladding itself can be considered. Turn to page 80.

The roof, too, must be sheathed, and for the same reasons as walls. That is, to provide rigidity, to form a surface for the installation of weather-proofing, to provide a surface for fastening. Required thickness of sheathing are shown below.

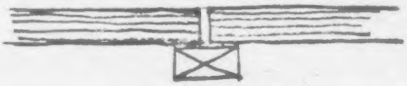
Spacing of Rafter or Joist in o.c.	Plywood thickness		Particle Board thickness Edges Supported	Boarding Less than 12" Wide
	Edges supported T & G	Edges Unsupported		
12"o.c.	5/16"	5/16"	3/8"	11/16"
16"o.c.	5/16"	3/8"	3/8"	11/16"
20"o.c.	3/8"	1/2"	7/16"	3/4"
24"o.c.	3/8"	1/2"	7/16"	3/4"

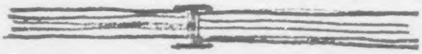
Plywood is considered to be unsupported at edges if one or more sides cannot be nailed to a support. See sketches under


Unsupported


Supported

However support can be provided with 2" X 2" blocking nailed between joists or rafters or metal 'H' clips can be provided.


Blocking


'H' clip

Once again selection of roof sheathing will depend upon the final finish to be applied to the roof. The nail holding capability of particleboard is less than either plywood or wood boarding and so is not so desirable in terms of quality, but does perform adequately, and is cheaper than the other materials

It should always be remembered that all materials expand and contract with temperature and moisture variations. Therefore it is essential to leave space for such movements to take place. Leave at least 1/16" between panels to allow for such movement. Boarding, as it is so much narrower, is rarely specified to have any particular tolerance left in assembly. The assumption, which is usually safe, is that wood will tend to dry out and shrink, thereafter movement will be of less significance. However, it is obvious that the boarding should not be cramped up tight, as any swelling would result in buckling of the sheathing.

All that is really achieved by leaving room for movement is a reduction in stress on the waterproof membrane.

Take an ordinary rubber band, hold it between finger and thumb in both hands so that about 1/8" separates both thumbs. Extend the band to about 3/4" and repeat several times. The rubber band takes this stress relatively well. Now repeat, but with thumbs separated by about 1/32". If you held the rubber band securely it probably broke. Most roofing materials are elastic, but far less so than rubber. What are your conclusions?

____

____

____

____

____

There are a vast array of materials offered to the designer as the ultimate answer to cladding buildings. Basically these are natural or artificial.

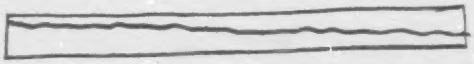
The natural materials include wood, stone and slate.

The artificial ones brick, concrete, asbestos, aluminum, steel, plastic, clay tile and so on.

In construction it is far easier to look at these materials in terms of thickness, and therefore methods of installation. These materials are used as cladding, thick materials as veneer.

Wood

Wood is produced in many forms for use as cladding. Some of the oldest and best are shingles, shakes, and weatherboarding. Shingles and shakes are produced mainly from cedar and redwood, as these woods have a greater re- sistance to decay than most others, and are easily cut or split to form the thin units known as shingles and shakes. Originally both shingles and shakes were hand split, they are now most frequently machine cut. When cut, the tendency is to shear through the cells of the wood, whereas splitting allows the wood to break without cutting through the cells. Splits, then are known to be less absorptive than sawing shingles and shakes. Unfortunately the large labour content makes them expensive. However, a hybrid is available where the wood is machine cut on one face and hand split on the other, providing the best of both worlds. The initial piece is split double thickness, and subsequently diagonally sawn.



hand split, machine cut

Shingles are usually manufactured in lengths of 16" 18" or 24", and are approximately 8" wide.

The amount of shingle or shake exposed after installation is known as the 'weather', on walls the amount exposed to the 'weather' is usually between 6" - 8", although this varies with the particular application.

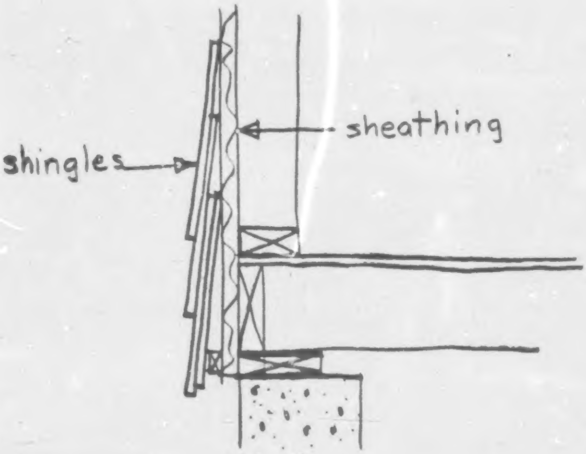
The following materials as applied to wood frame construction are (claddings) (veneers) wood, asbestos, steel, aluminum, plastic, slate, clay, tile.

Check appropriate statement.

Wood, asbestos, steel, aluminum, plastic, slate and clay tile are all cladding materials. The veneer materials include stone, brick and concrete in small and large units.

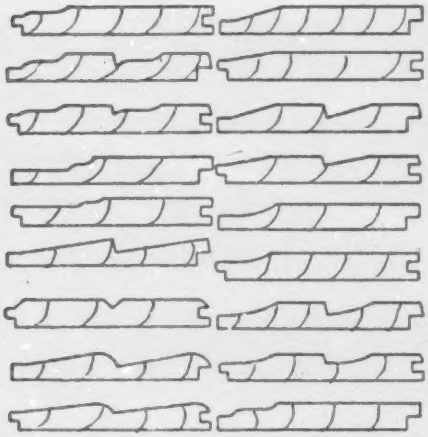
A shingle is defined as a piece of wood thinner at one end then the other, produced by sawing.

A shake is also thinner at one end than the other as butt, but is split, not sawn, usually by hand. Aesthetically shakes are preferred by many architects because of the texture and random appearance that results from their use. Shakes are usually thicker than shingles, much rougher in texture and variable in size and thickness.



Shakes & Shingles are applied as shown in the sketch above.

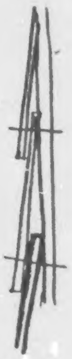
Wood siding, sometimes known as novelty siding or drop siding, consists of boarding usually 16' long and variable in width usually between 4" - 8". This kind of siding can be used without sheathing, but this is not recommended except for temporary structures. The range of profiles is shown below.



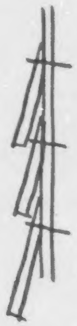
(a) Typical Profiles, Drop Siding

Although it is possible to start at the top of the building and work down to the bottom due to the tongue and groove of shiplap feature of these boards, thereby avoiding scaffold marring of the surfaces; the boards must be wedged up tightly to each other, if they are to perform satisfactorily. Nailing, at least two per support is through the face, and therefore, even when puttied in, shows on the face.

Lap siding or bevel siding is the same profile as shingles and is applied to the wall in a similar way to shingles. These boards should lap at least 1 1/2" preferably 2" to prevent water penetrations. If the boards are narrow they can be nailed through the top, so hiding the fastening, otherwise they must be nailed through the butt or thick end so that each succeeding course is nailed through the preceding one.



Wide boards
nailed through head & butt



Narrow boards
nailed thorugh head only.

Note that in all cases the top of the foundations wall is covered by the cladding.

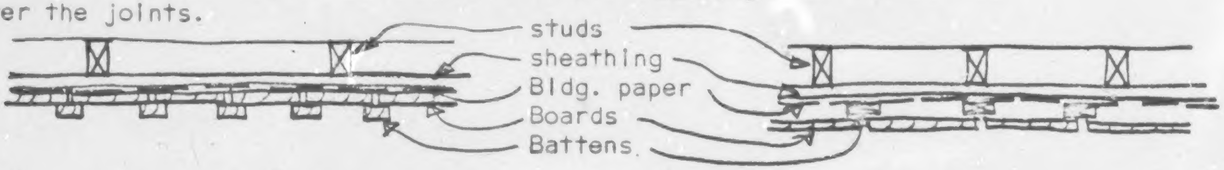
Slates and tiles, popular in Europe, are applied in a very similar way to shingles and will not be enlarged upon here except to say that properly used they are tremendously durable.

In all cases where a cladding is used, entire dependence for weatherproofing is not left to the cladding, all are always fastened over a waterproof membrane, usually heavy asphalt coated paper, sometimes asphalt coated felts.

Prepare sketches to show wall assemblies clad with narrow boards, wide boards, and shingles at a scale of 1 1/2" = 1'0".

Vertical boarding has no advantages over horizontal boarding or shingles in use, but frequently it is selected for its aesthetic value. Sheathing and building paper must be provided over the frame, and to this the vertical boarding is nailed. Boards should if possible run the entire height of the wall. Two types of board are principally used - square edge boards and tongued and grooved boards.

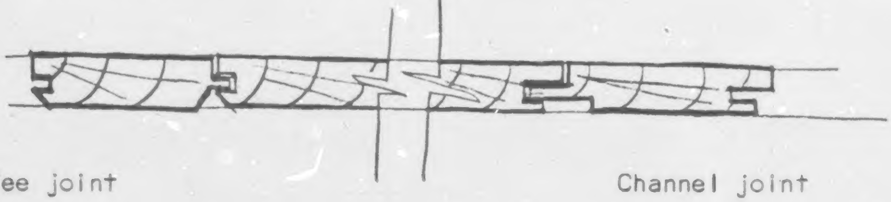
If square edge boarding is used. It is bedded in caulking compound at the joints and driven up tight. The joints are then covered with a nailed on wood batten. It is possible to produce a variety of effects by varying the widths of boards, and battens and to place battens under instead of over the joints.



Battens over

Battens under

Tongued and grooved boarding is also applied over building paper and sheathing. Unless special arrangements are made to emphasise the joint, a plane unbroken surface results. However because movement takes place it is usual to emphasise the junctions of boards by making a vee joint or channel joint in the boarding.



Vee joint

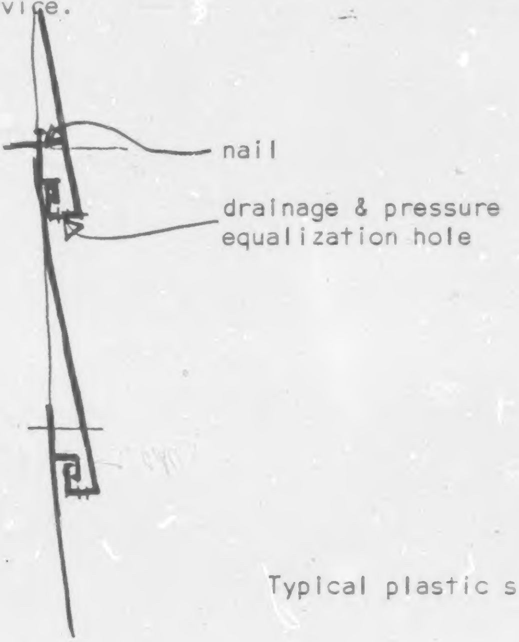
Channel joint

'Patent' Cladding embraces aluminum & steel strip formed siding, asbestos cement siding, pressed board siding and plastic siding all of which are usually supplied with a baked on enamel finish coat, thereby reducing both first cost and maintenance.

But they have disadvantages as well as advantages, steel can be dented, will rust if chipped or broken and can magnify the sounds of impact from rain, hail etc. It can also hold an electrical charge, and should therefore be grounded.

Aluminum is easily torn, and dented, but is less susceptible to oxidation than steel.

Plastic (usually poly vinyl chloride or PVC) siding does not suffer from the same difficulties as the metals, but has problems of its own. It is too early to be sure but fire resistance, resistance to weathering and colour stability and resistance to paint solvents are likely to be a source of difficulties in service.



Typical plastic siding

Cladding is used as a) A protective finish to structure

b) An aesthetic skin

c) To waterproof the structure

d) As a primary weather barrier

Cladding is used as a primary weather barrier. It should only be considered as part of a system. Theoretically the wall is composed of four elements.

1. Structural element
2. Air barrier
3. Thermal barrier
4. Moisture or weather barrier

In some materials, some of these functions can be combined. In others they cannot. Broadly speaking Prefabricated techniques attempt to include as many functions as possible in the same material, whereas on site technique deal with each aspect separately. All elements are important, some however must be protected from mechanical injury, for example insulation is usually brittle, plastic vapour barriers are easily torn. Thus a typical wall constructed on site consists of:

Internal finish (protects interior of wall)

Air barrier

Insulation

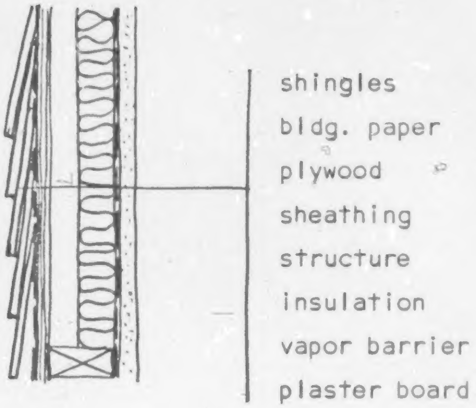
Structure

Secondary weather barriers

Primary weather barriers.

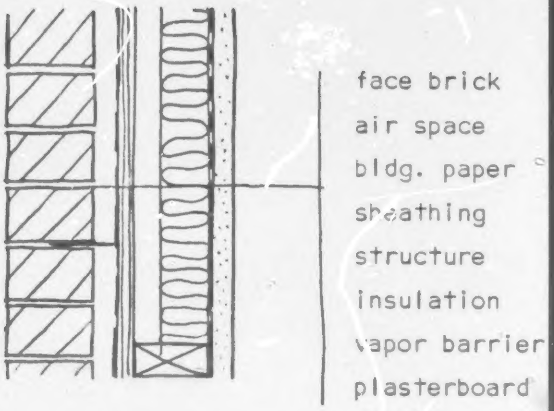
Draw a series of 4 wall sections namely the materials and their functions, three of them using traditional means, and the fourth combining functions with the minimum of materials. If you cannot do this, turn to next page. If you can, turn to p. 90.

1


shingles
bldg. paper
plywood
sheathing
structure
insulation
vapor barrier
plaster board

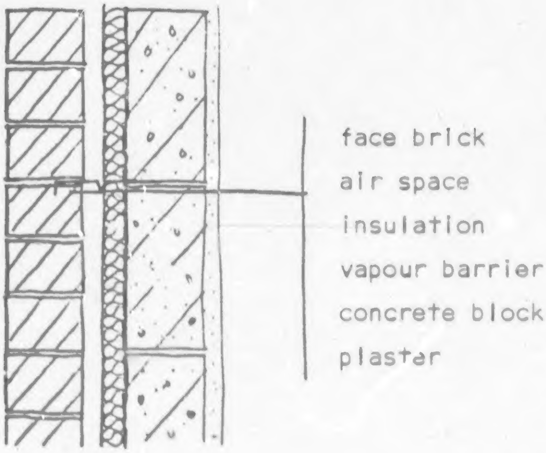
Typical shingled wall

2


face brick
air space
bldg. paper
sheathing
structure
insulation
vapor barrier
plasterboard

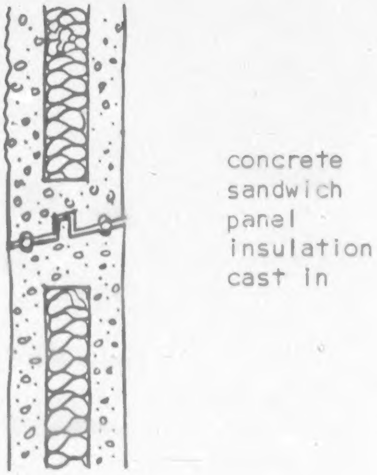
Typical brick veneer wall

3


face brick
air space
insulation
vapour barrier
concrete block
plaster

Typical masonry cavity wall

4


concrete
sandwich
panel
insulation
cast in

Typical concrete sandwich panel

In order to reduce the impact of thermal movement on components and structure it is desirable to keep the majority of the building at as even a temperature as possible.

Theoretically, if an insulation material could be found that was impervious to moisture, was structurally strong enough to carry loads and was of low permeability, walls could consist of a single element. However, no such material presently exists.

An attempt has been made in the development of concrete sandwich panels to achieve a reduction in the number of materials. But this requires concrete of extraordinary strength and quality, and demands a very high standard of quality control and accuracy. Even so, difficulties develop at joints, and these require extreme care in design and execution. See page 89, sketch 4. This type of panel is economic only if made in sufficient quantity.

Successful systems rely upon taking advantage of natural phenomena. The greatest problem is rain leakage. This can only take place:

1. If there is water present

2. There is a hole through which it can move.

3. There is a force present to drive it through the hole.

In order to keep thermal movement to a minimum should one

a) Keep the building warm

b) Insulate the building thoroughly

c) Keep the building cool

d) Maintain the structure of the building at an even temperature

Check one

If you checked a), b) or c), turn to page 89, before reading on.

To maintain the structure of the building at an even temperature requires placement of insulation

a) Within the external walls?

b) On the inside face of the external walls?

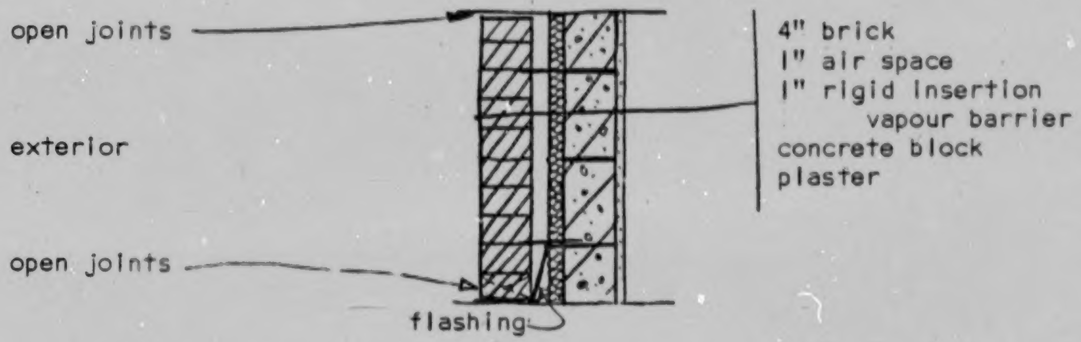
c) On the outside face of the external walls?

Check one

On the outside face of the external wall, so that the majority of the building is at an even temperature. Unfortunately this is presently only an idea. A protective material must be placed over the insulation to protect it. But it is possible and desirable to insulate the major mass of the wall and building.

This partly explains the success of shingle walls. The external protective skin, made up of small overlapping units, is able to absorb movement, while the majority of the mass of the wall is kept at an even temperature. Additional to this success however is the fact that air spaces are formed between the shingles and the sheathing, thus permitting pressure equalization. This is sought in many walls.

Typically, though, a continous air space is produced between the component parts of the wall.

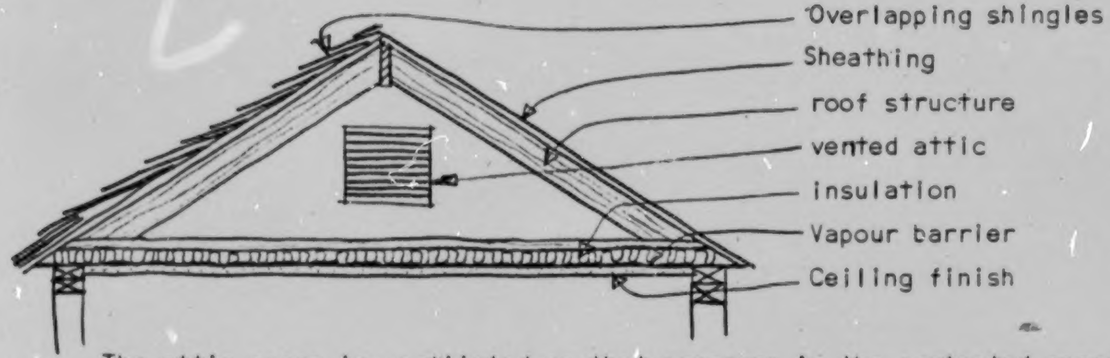


The interior wall is made as tight as possible the outer skin is assumed to leak, but the cavity allows water to drain out, and for pressure to equalize. Properly executed this wall will not leak. But mortar must not be dropped on masonry ties, ties must be arranged to pitch outward, and weep holes at bottom of wall must be clear.[1]

---

[1] For further information on this aspect see Canadian Building Digest 21 "Cavity Walls" T. Richie.

Similar considerations apply to roofs as to walls. Probably the most successful roof form is the pitched type. They usually work well because they take advantage of natural phenomena. Their attributes were originally developed by tradition. Now we know why they work so well.

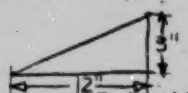

Overlapping shingles
Sheathing
roof structure
vented attic
insulation
Vapour barrier
Ceiling finish

The attic space is ventilated so that pressure in the protected space is equal to outside air.

The slope of the roof allows gravity to assist with draining the roof surface.

The small overlapping units (shingles) permit movement without rupture.

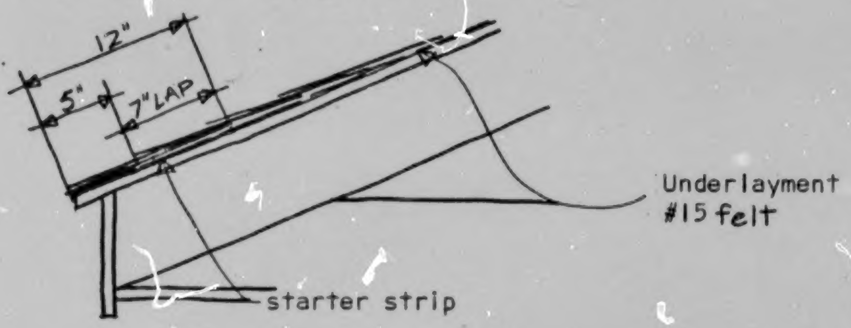
The insulation and vapour barrier are protected.



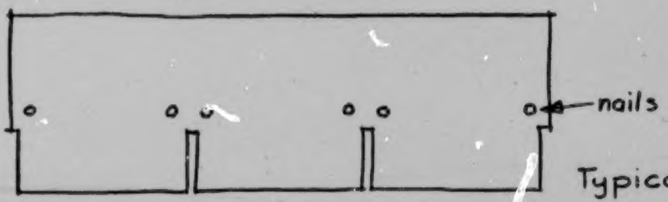
The slope of roof is expressed either in inches per foot, e.g. 3 in 12 is 3" in 1'0" or in degrees 3 in 12= 15°

This is the minimum pitch for wood shingles; for 210 lb. asphalt shingles the minimum pitch is 4 in 12. Lower pitches required different materials, although frequently essentially flat roofing techniques are used.

Installation of asphalt shingles (typical)



Note that there is a minimum of two shingle thicknesses at any one point, including the roof verge. A starter strip 12" wide is used, which is usually a strip of 19" selvage roofing known as N.I.S., or a reversed shingle.



Typical 210lb shingle.

Shingles are nailed to roof, and, where conditions are windy or pitch is low, glued as well. Therefore, the roof deck must be nailable, 6" X 1" boarding or 1/2" plywood are often used.

An underlayment is used for two reasons.

1. To act as a secondary moisture barrier

2. To act as a 'slip sheet', permitting the system to move without affecting or being affected by the deck.

A pitched roof is satisfactory because

a) It uses overlapping units

b) It permits ventilation of the attic space

c) It uses gravity to advantage

d) It does not require to be perfectly sealed.

Check one.

The principle advantage of the pitched roof is that a perfect seal between the units is not neccessary. Flat or near flat roofs require a perfect impermeable membrane to ensure adequate performance.

A flat roof is very like a tray. If the tray is punctured most of the moisture will penetrate through the hole.

Unfortunately holes must be made in flat roofs so that vent pipes, drains ventilators and other items can be installed.

a) A pitched roof requires a perfect impermeable membrane for successful performance.

b) A flat roof requires a perfect impermeable membrane for successful performance.

Check I and turn to page 99.

If you checked (A) turn to page 97

If you checked (B) turn to page 100

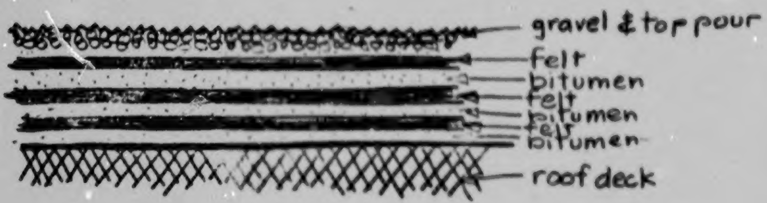
A flat roof is provided with an impermeable membrane which may be of a number of materials.

Most common is the bituminous roof made of either coal tar pitch or natural or refined asphalt.

Bitumin is a viscous fluid which hardens to form a waterproof membrane. In itself it is insufficiently strong to withstand temperature movement. Therefore it must be reinforced with a material to which it must bond to provide an acceptable tensile strength.

Usually this reinforcement is felt, impregnated with bitumen. Felts are either made from organic or inorganic material. The most popular materials are wood pulp, asbestos and glass fibre.

Typically, a flat roof is built up from a number of layers of felt interspersed with moppings of bitumen. It is usually considered that the greater the number of plies of felt and moppings of asphalt used, the longer the service life of the roof will be.



3 ply roof
(expected life 15 years)

In a built up roof the waterproofing is provided by

a. the felt
b. the bitumen

Check one. If you chocked a., turn to page 102, of b. page 104.

In a built up roof the waterproofing is provided by the bitumen. The felt in itself is hygroscopic and will absorb water without forming a barrier to water ingress.

The felt is a reinforcement for the bitumen. In special cases the felt is coated with bitumen and chippings at the manufacturing plant so that the composite product is in itself waterproof, but the felt is still only reinforcement. Coated felts are used successfully as vapour barriers, and as intermediate plies. They have advantages over impregnated felts in that they are less likely to suffer from moisture pick up during construction, but are stiffer and heavier to handle and as less bitumen is used between plies, lamination of plies is sometimes unsuccessful.

Felts are referred to by their weight based on an approximate area of 100 square feet or as it is known in the roofing trade "a square".

So No. 15 felt weighs 15 lbs/100 sq. ft.
No. 40 felt weighs 40 lbs/square .
and so on.

A built up roof is reinforced a. with felt
b. with bitumen

Check one.
If you checked a. turn to page 104

If you checked b. turn to page 100

In a built up roof the waterproofing is provided by the bitumen, the felt acts as a reinforcement. Bitumen is a generic term that covers two basic materials

1. Coal tar pitch
2. Oil based asphalt.

Coal tar pitch is a by product of coking coal.
Its softening point is 140° - 155° F
Application Temperature 325° - 375° F
and its maximum heated temperature 450°F. Above this point essential oils boil off so that the material when it hardens, cracks. Coal tar pitch remains softish in use and is self healing (due to flow when heated by the sun). This advantage becomes a disadvantage, for it can only be used on flat or near flat roofs.

Asphalt occurs naturally in the asphalt lakes of Trinidad (known as Lake Asphalt), in rock in various parts of N. America (known as rock Asphalt); and as part of the distillation of Petroleum, simply known as asphalt. The naturally occurring asphalts are claimed to be superior to those produced by distillation but there is no evidence offered to support this contention.

There are three types of asphalt, Type I for use on flat roofs, slopes up to 1" in 1'0"; Type 2 for use on roofs with slopes from 1" to 2" in 1'0"; and Type 3 for use in roofs with slopes in excess of 2" in 1'0".

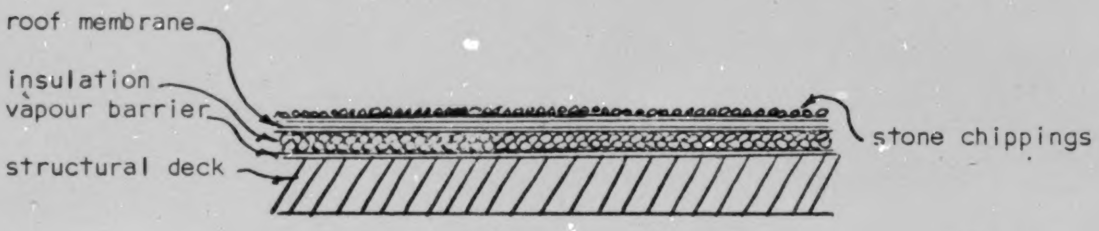
	Type 1	Type 2	Type 3
Softening Point is	140 - 150° F	165 - 175° F	190 - 205° F
Application Temperature	350 - 400° F	375 - 425° F	375 - 425° F

Its maximum heated temperature is 500° F.

All bitumens creep, therefore a reinforcement must be used to complete the built up roof system. Turn to page 102 for further information on felts before proceeding to page 105.

Pitch and asphalt are not compatible with one another and in addition, pitch cannot be used successfully with some insulation materials.

The traditional flat roof is made up of



Insulation can be of:	Limitations	Thermal conductivity K
Fibreboard	susceptible to moisture pick up	.35
Glass fibre		.27
Polystyreme foam	cannot be used with pitch must be protected from solvents and temperatures over 165° F	.20
Polyurethane foam	cannot be used with pitch, must be protected from solvents and temperatures over 375° F	.15
Cellular glass		.40
Straw fibre	Susceptible to moisture pick up	.33
Cane fibre	Susceptible to moisture pick up	.33
Mineral fibre		.38

All insulation must be protected from the elements.

Pitch (is) (is not) compatible with asphalt and (can) (cannot)
(a) (b) (a) (b)

be used with urethane insulations

Check appropriate words

If you checked a, turn to page 107.

If you checked b, turn to page 108.

Pitch is not compatible with asphalt and cannot be used with urethane insulation.

The effect of using them together is that a good bond cannot be achieved, so that gaps remain between laminations permitting the contained air to expand and contract with temperature changes, leading via a progressive system to early membrane failure.

In order to protect the bitumen from the harmful effects of the sun's rays, and as protection from fire occuring outside the building, burning brands, for (instance a layer of light coloured chippings) is applied to the top surface of the roof.

Because wind can blow this gravel off the roof, it is normally applied as a "double pour", if the roof is near flat. This consists of pouring bitumen onto the roof, spreading gravel over it while still hot, brushing off loose gravel when cool and repeating the operations. The single pour method used on roofs with slopes greater than 1/2" in 1'0" simply consists of pouring bitumen on the roof and embedding chippings in it.

Gravel surfacing on a roof is provided to:

a. Protect the bitumen from the sun's rays

b. Act as an aesthetic finish

c. Act as fire protection

d. Act as a traffic surface

Check the appropriate statements

Gravel surfacing on a roof is provided to protect the bitumen from sun, firebrands, and to provide an aesthetic finish. No gravel surfaced roof can be safely trafficed. Special means must be used to provide waterproof traffic surfaces.

Excessive traffic, i.e. traffic other than for maintenance access, can quickly result in chippings being driven through the bituminous membrane resulting in rapid failure of the roof system. Leaks in flat roofs are difficult to locate and repair because of the gravel surfacing. Thus attempts have been made to find substitute finishes. Two methods are in use:

1. Mineral coating of felts at the factory

2. Application of a reflective coating to the roof surface.

The first method employs the use of coated felts for the final roof surface shown as NIS or nineteen inch selvage rool roofing. It is quite satisfactory in use, but is difficult to install without staining the mineral surface with bitumen while still maintaining full adhesion between plies, consequently it is normally used on roofs of minimum pitch 2" in 1'0", where occasional lack of perfect adhesion is not a serious problem.

The second method does not have the problems of the first, but it is in reality nothing more than an asphalt based paint, so that its service life prior to recoating is normally no more than five years.

NIS is (a) satisfactory (b) unsatisfactory as a finished surface for a traffic free roof.

A roof coating is (a) superior (b) inferior to NIS as a roof finish.

Check appropriate statements.

NIS is satisfactory as a finished surface for a traffic free roof, but if it were to be used on a roof normally accessable to people, its mineral coating would soon wear away leaving the felt itself exposed to the elements. In any case the roof would be uncomfortably steep. A roof coating is generally inferior to NIS, but it can be used on roofs sloped less than 2" in 1'0" which NIS cannot. The service life of NIS is normally in excess of 15 years.

Obviously there is no simple answer to these questions, as is the case with many problems in architectural design and construction. Selection of solutions depends upon factors contained in the specific problem.

The most important part of any roofing job is that is should keep moisture out of the roof structure, both from above and below.

Moisture entry from below the roof structure is controlled by

a) The roofing membrane

b) The insulation

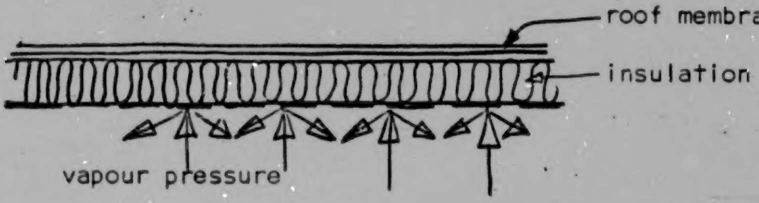
c) The structural deck

d) The vapour barrier

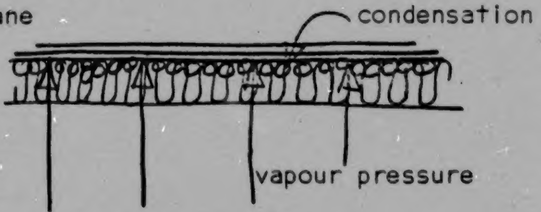
Check one

Moisture entry from below the roof structure is controlled by the vapour barrier.

It is not neccessarily stopped by the vapour barrier, because vapour pressure is almost always present. The vapour barrier, which may be of tared paper, polyvinyl chloride film, bituminous felt, bitumen or any other low permeability material is best placed on the warm side of the insulation on top of a rigid supporting deck or surface. It must be continous. No breaks or tears can be allowed. If the vapour barrier is faulty, or does not exist, early failure of the roof membrane will result.



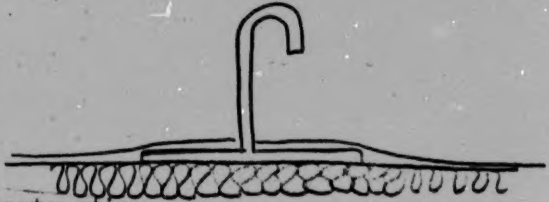
with good Vapour Barrier



without Vapour Barrier

In order to relieve vapour pressures within roofs, insulation breathers are sometimes used, usually one very 100 sq. ft.

This solution to the problem has rarely been entirely satisfactory, and so coupled with the problem of increasing usage of roofs as pedestrain areas and as landscaped surfaces new methods of roofing are gaining acceptance.



For much more detailed coverage of methods of constructing flat roofs see A/V presentation no.

The conventional flat roof is heir to a number of difficulties.

1. It requires perfect workmanship to perform satisfactorily.
2. Repair of flat roofs, particularly when gravelled, is difficult.
3. The "sandwiching" of insulation between two impervious membranes can cause trouble if moisture becomes trapped within.
4. It is a relatively fragile surface.

Thus a practical alternative has to be found. The most hopeful roof type that has yet been developed is known as the "protected membrane roof", and the concept is extremely simple. The vapour barrier becomes the only waterproof membrane, and the insulation is placed on top of it. There is rather more to the system than this of course, but this is the essential difference.

The basic requirements of materials for protected membrane roofs are:

1. The membrane must be tough smooth and moisture resistant .
2. The insulation must be capable of withstanding direct exposure to the elements, without losing its insulation value.
3. The deck must be smooth, rigid and sloped to drains.

Which of these insulation materials can be used exposed to the elements on a roof?

a. Glass fibre b. Fibreboard c. Polystyreme foam

d. Polyurethane foam e. Cellular glass f. Straw fibre

g. Mineral fibre.

Check the appropriate materials and turn to p. 116.

None of these materials can be used exposed to the elements on a roof. All are adversely affected by one or more of the conditions experienced in the open. As an experiment, obtain samples of at least four of these materials and using the facilities of the Construction Lab subject them to immersion in water (24 hours) freezing (24 hours) exposure to ultra violet radiation (24 hours).

The following experiment must be undertaken in the Construction Lab

---

Intent

To observe the effect of freezing and thawing and ultra-violet light on various types of insulation.

Theory

Water when reduce in temperature to freezing has the ability to expand with great force. Materials that draw up water by capillary action retain this water even when subjected to freezing. If the structure of the material does not allow movement for the expansion, then that material must make room for it by other means.

Method

1. Obtain samples of four different kinds of insulation.
2. Immerse samples in water in container for 24 hours.
3. After 24 hours, drain of most of the water (leaving about 1/2").
4. Place container of samples in freezer for 24 hours (using the ultra violet light).
5. After 24 hours, take container of samples out of freezer and immerse in water which is at room temperature for 24 hours.
6. After 24 hours place container in freezer for 24 hours (not using ultra-violet light).

Report

Note any changes in various types of insulation on a weekly basis.

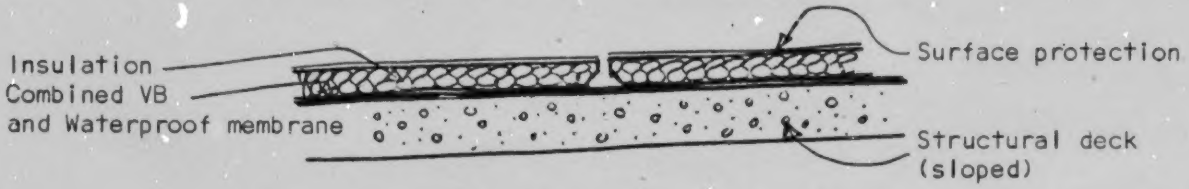
2/116

FJE:bdr

Your results will indicate that only some of these materials survive these tests unscathed, and if you inspect samples exposed over long periods to the outside environment, you will find that none of them are entirely satisfactory.

Therefore all insulation must be protected, although the kind of protection needed will vary with the material.

Thus the protected membrane roof will take the form as below.


Insulation
Combined VB
and Waterproof membrane
Surface protection
Structural deck
(sloped)

The surface protection provided for the insulation where it is not generally accessable can be

a) a water resistant material

b) a material opaque to ultra violet

c) a reflective material

d) an elastic material

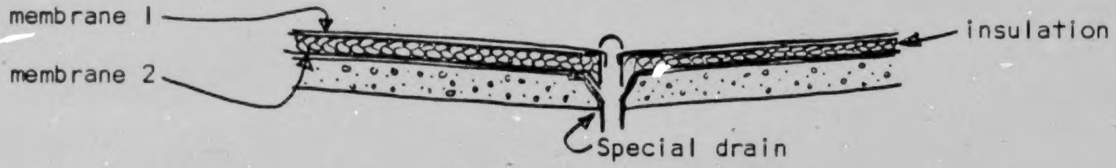
e) a heavy material

Check the appropriate choice.

The surface protection provided for the insulation where it is not generally accessable can be a material opaque to ultra violet light.

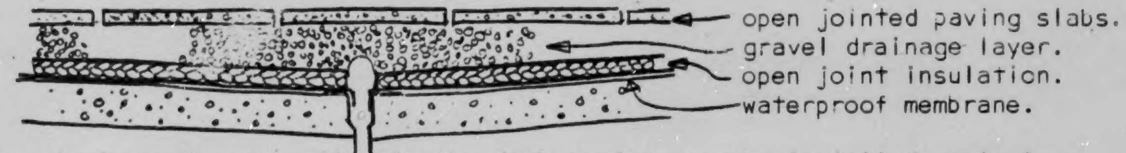
There are two main classifications of protected membrane roof.

1. The roof which provides two waterproof membranes as the sketch below.


membrane 1
membrane 2
insulation
Special drain

The special drain allows water vapour to evaporate from between the two membranes and from the insulation, and also drain the lower membrane if water should find its way down to that level.

2. The roof which provides one waterproof membrane as the sketch below.


open jointed paving slabs.
gravel drainage layer.
open joint insulation.
waterproof membrane.

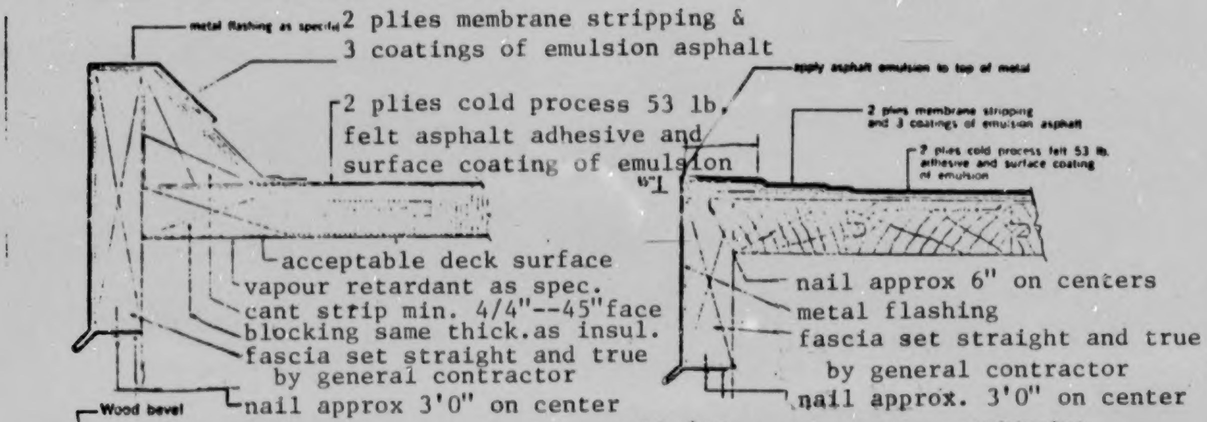
The single membrane applied to the deck surface can be installed early in the project sequence, any leaks developing can be detected and repaired prior to final completion. The roofing system can be completed after all work operations which might cause damage have been completed. The principles involved in flat roofs are quite simple. Complications arise only when dealing with flashings and at protrusions through the roof surface.

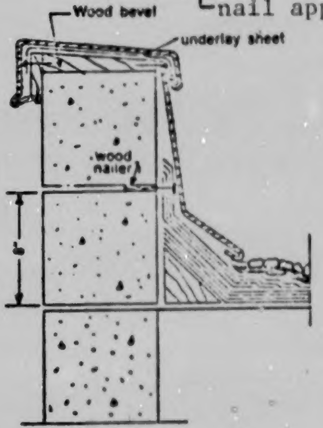
Perimeter of roofs are finished on variations of two basic themes

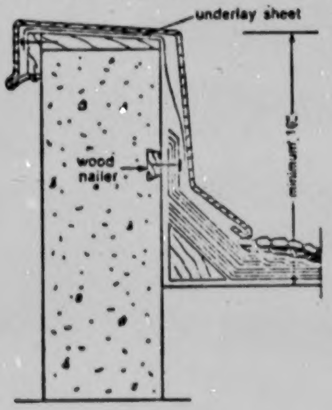
a) the overhanging roof

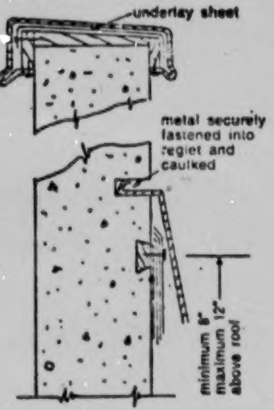
b) the parapet wall

Typical overhanging roof type


metal flashing as specified
2 plies membrane stripping & 3 coatings of emulsion asphalt
2 plies cold process 53 lb. felt asphalt adhesive and surface coating of emulsion
1"
acceptable deck surface
vapour retardant as spec.
cant strip min. 4/4"--45"face
blocking same thick.as insul.
fascia set straight and true by general contractor
nail approx 3'0" on center
apply asphalt emulsion to top of metal
2 plies membrane stripping and 3 coatings of emulsion asphalt
2 plies cold process felt 53 lb. adhesive and surface coating of emulsion
nail approx 6" on centers
metal flashing
fascia set straight and true by general contractor
nail approx. 3'0" on center


Wood bevel
underlay sheet
wood nailer
8"


underlay sheet
wood nailer
minimum 16"


underlay sheet
metal securely fastened into reglet and caulked
minimum 8" maximum 12" above roof

Flashings are usually made from sheet metal - copper, lead, zinc, galvanised steel, stainless steel, oraluminum, and sometimes from NIS felt, copper coated fibreen, fibre glass reinforced plastic and a number of other less usual materials.

The requirements of a flashing material are: 1. That it should be impervious to moisture, 2. Non corroding. 3. Compatible with other materials used in system 4. Easily worked. 5. Low in cost.

The most commonly used material for average quality work is aluminum, usually embossed to mask the inevitable wrinkles and buckles that occur with temperature change and movement.

Draw typical details of roof/wall connection and overhanging roof in wood frame construction at 1 1/2" - 1'0" scale. Instead of the traditional flat roof shown in the details on page 120, adapt the details to apply to a protected membrane roof.

Flashings are used to

a) Provide a neat appearance where roof joints other elements.

b) Provide a robust finish at points susceptible to impact damage.

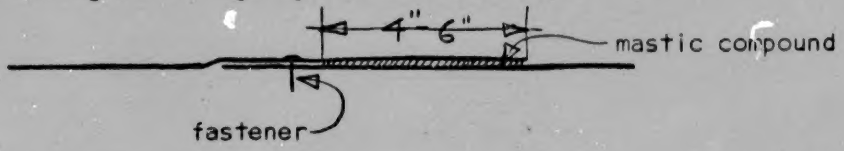
c) Provide a watertight connection at changes in materials

d) Provide a flexible watertight connection at changes in materials

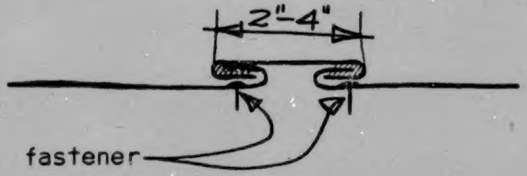
Check I.

Flashings are used to provide a flexible watertight connection at changes in materials. They should also fulfil the requirements of a. b. and c, but the primary purpose is as stated above.

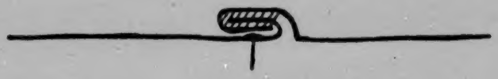
Because flashings are constructed of materials with finite dimensions, methods of making water tight joints must be used.



1. Simple lap joint

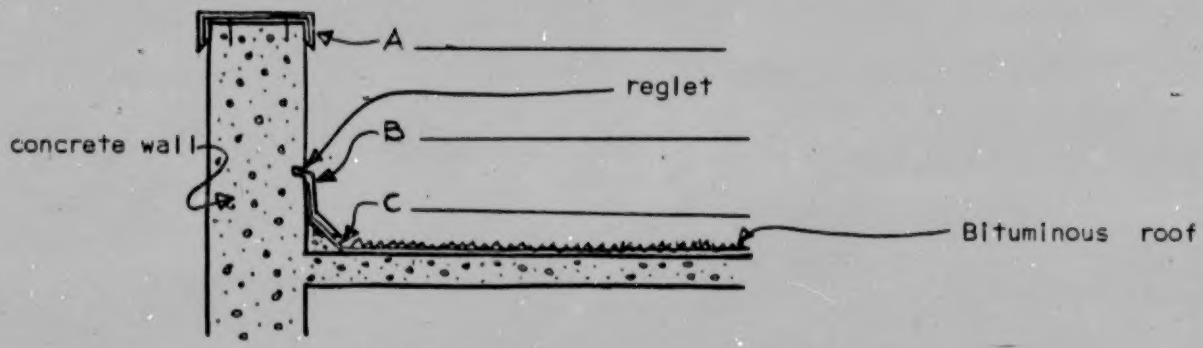


2. Cap strip joint



3. Interlocking joint

These connections are particularly applicable to sheet aluminum. Soldering of materials such as copper was frequently used in the past, but high labour and material costs make this technique unusual at the present time.


A
reglet
B
concrete wall
C
Bituminous roof

Name the flashings at A, B and C above.

A is a cap flashing

B is a counter flashing

C is a base flashing

A & B are aluminum, C is bituminous.

Note that the cap flashing uses a galvanised strap to provide concealed fastening for neatness of appearance and water tight connections. In this case the flashing is snapped into position.

The top of a cap flashing should be

a. flat

b. sloped

c. sloped towards roof

d. sloped away from roof

Check I

The top of a cap flashing should be sloped. The direction of slope is not critical to the performance of the flashing itself, but it is usually arranged to slope towards a drained surface. The area of flashing is usually so little, that there is no noticeable increase in the amount of precipitation apparent to persons standing below.

The design and detailing of roofs for satisfactory performance is no simple matter, but it is basic knowledge that all architects are expected to be conversant with.

Further information can be obtained by reviewing A/V presentation number

Draw an anoonometric or isometric of the parapet and roof flashing details as shown on page 124 at scale of 1" - 1'0", and with joints at 4'0"o.c.

The basic principles of moisture penetration are

1. There must be moisture present
2. There must be a hole through which it can move
3. There must be a force present to move it inward. To which building elements do these statements apply?

a. Floors b. Walls c. roofs d. windows e. doors

The basic principles of moisture penetration apply to all building elements. Floors, walls and roofs have been covered in the preceeding pages, together with aspects peculiar to the element under consideration. Windows generally are required to provide specific benefits. Although designers have been known to make use of the window, (then known as a 'void') as purely compositional emphasis, the window has specific and straight forward functions to perform.

It must 1. Admit light

2. Provide view

3. Provide ventilation (often but not always)

4. Act as a separator between inside and outside environments.

With the current state of technology windows are

a) Neccessary to admit light

b) Neccessary to provide ventilation

c) Neccessary to provide a view

d) not neccessary

Check the appropriate statement.

With the current state of technology windows are not neccessary. This of course is purely a technological view point, but, in fact, some buildings have been completed without them. It is doubtful that windowless buildings, except for very special purposes, will ever gain full acceptance. However, it is generally accepted that an abundance of windows particulariy on South East and West exposures is environmentally undesirable and excessively expensive in terms of energy usage.

Refer to Canadian Building Digest No. 39 Solar Heat Gain through glass walls.

Large areas of glass in the external walls of a building are undesirable because

a) Excessive glare is produced

b) Excessive heat gain results

c) Condensation occurs on glass

d) Cold drafts occur

e) They are expensive

f) Excessive heat loss occurs

g) They leak

h) They are expensive to install and maintain

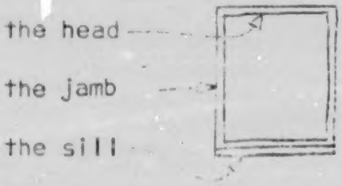
Check the applicable statements.

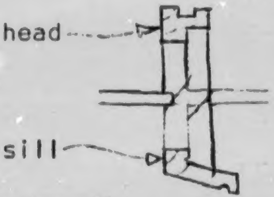
Large areas of glass in the external walls of a building are undesirable because excessive glare is produced, excessive heat gain results and excessive heat loss occurs. These are the technical reasons for reducing numbers and size of windows.

You would not have been wrong if you checked any or all of the other statements, but these problems result in the main because of items a, b, and f.

All of these problems can be taken care of by careful sizing, orientation and design of windows.

A windows parts are known as

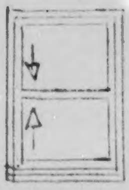




Where groups of windows are connected together to form larger windows the vertical members are known as millions, and the horizontal members as transoms subsidiary members within the window itself, reducing the sizes of the glass panes are known as glazing bars.

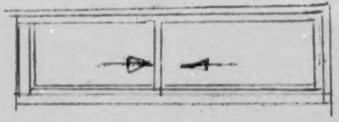
All these parts have been related to fixed windows, that is, no part opens for ventilation.

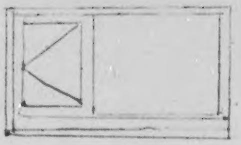
There are an almost bewildering variety of opening windows, and certain conventions are used on elevations drawings to indicate the method of opening.



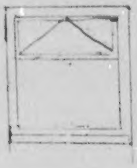
This is a double hung or vertical slide window. The arrow indicates which windows move and in which directions.

This is a horizontal sliding window.

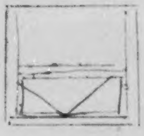




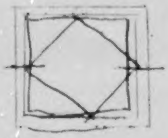
This is a casement window, that is the ventilator opens hinged on the side indicated by the dotted arrow head. Indication of whether it opens in or out must be noted in the drawings or specifications, otherwise it is assumed to open out.



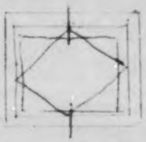
This is a top hung window or awning window, unless indicated otherwise it is assumed to open out.



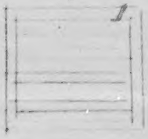
This is a bottom hinged or hopper window. Unless indicated otherwise it is assumed to open in.



This is a horizontally pivoted window. The short lines through the jambs indicate the locations of the pivots.



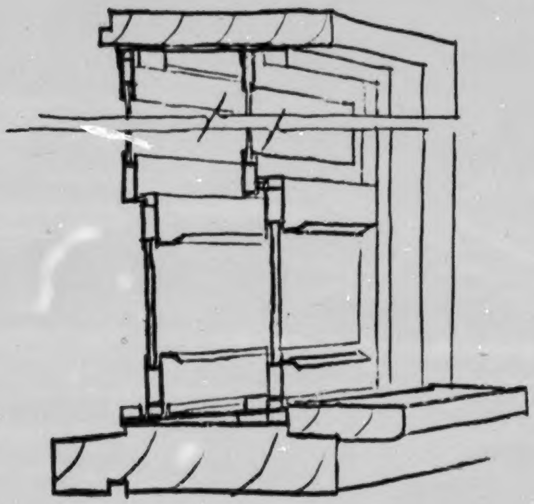
This is a vertically pivoted window. The short lines through the head and sill indicate the location of the pivots.



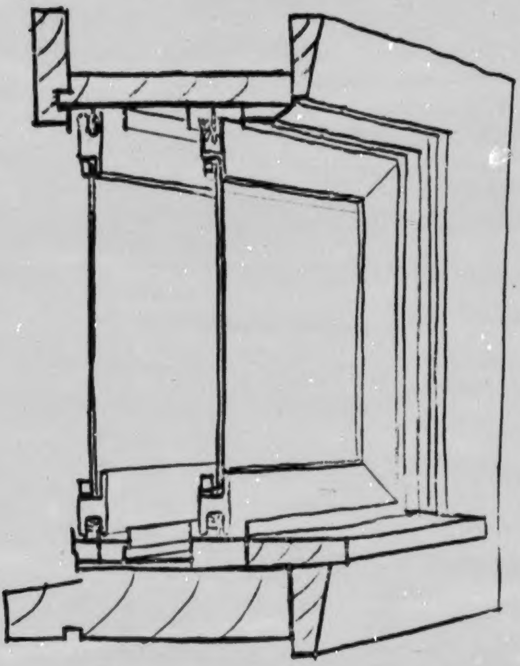
This is a jalousie window in which each glass blade pivots as a louvre.

There are additional variations on these windows. Mechanisms which move the pivot points away from the frame of the window are known as projected windows. The addition of further systems of sliders into sliding windows changes them to become 'double double hung' and double horizontal slide windows.

Make perspective sketches of a 'double double hung' or a double horizontal slide window, and a sketch section through each type, not to scale.



The double double hung window should look something like this.



The double horizontal slide window should look something like this.

Currently double horizontal slide aluminum windows are very popular, and can work extremely well in residential construction.

A large number of materials are used for fabricating windows. The traditional material, and still excellent if carefully designed and manufactured is wood.

Windows are made as well from extruded aluminum,pressed steel, hot rolled steel, stainless steel, lead, bronze and plastic, with permutations of most of these materials. It is also possible to glaze directly into masonry, wood, and concrete structures.

Comprasion of Properties of the three most popular window materials.

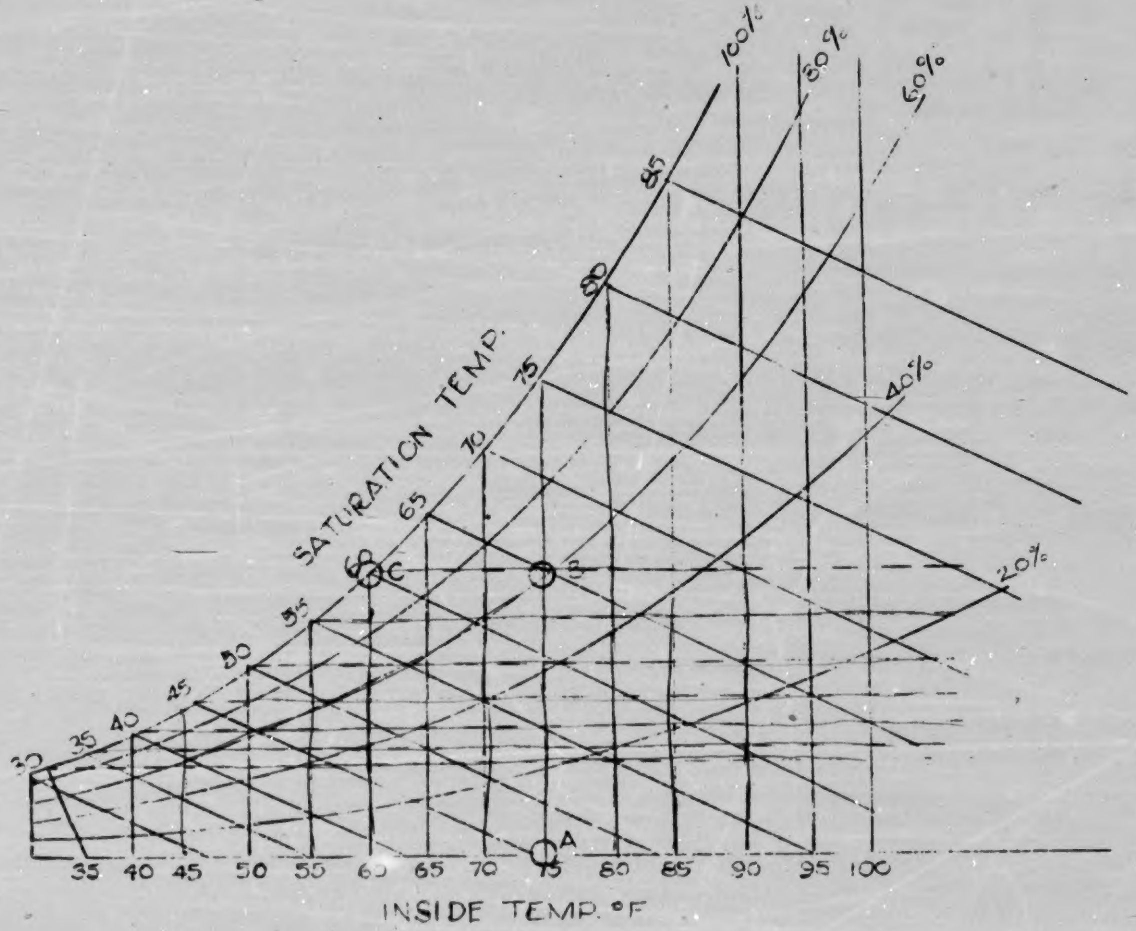
Material	Coeff. of Thermal Expansion		Thermal Transmission	Moisture Movement
	per deg. F	in/100'/100°		
Wood		1/100"	°96 Btld./Mr/Ft^2 1" thick per °F	
Steel	7X10-6	3/4"	21.60	Nil
Aluminum (anodised)	14X10-6	1 1/2"+	154.80	Nil

From these figures it can be seen that these materials are significantly different in performance, the advantages of one material may be disadvantages in others. For our purposes at the moment the most important factor is thermal transmission, for this is the most obvious and most annoying problem that is faced in otherwise satisfactory windows.

The most obvious effects of high thermal transmission in window frames is condensation, and when temperatures are very low, icing.

Icing will occur a) When outside temperature falls to 32°F b) When inside temperatures fall below 32°F c) When surface temperature falls below 32°F with condensation present.

Icing will occur when the surface temperature of the glass or frame at the inside surface falls below 32°F. with condensation present.



SIMPLIFIED PHSYCHOMETRIC
CHART AFTER ASHRAE

From the chart above, it can be seen that air at 75°F with a relative humidity of 60% (a reasonably comfortable level) will be at saturation level at 60°F approx. Below this temperature it will begin to be apparent on window glass and frames as condensation.

Repeat this excerise with temperatures of 70°F and relative humidities of 30% 40% and 50%. Record your readings.

1. ______________________________

2 ______________________________

3. ______________________________

At 70°F and 30% R H Saturation is reached at 36°F
At 70°F and 40% R H Saturation is reached at 45°F
At 70°F and 50% R H Saturation is reached at 50°F

Between 40% and 50% R H is usually considered to be most comfortable, but the average maintained in Canadian Homes is usually less than 30% R H and frequently as low as 12%. At these low levels discomfort is experienced in several ways, not least of which is a feeling of chill, with consequent raising of temperatures by artificial means to closer to 80°F which compounds the condensation problem.

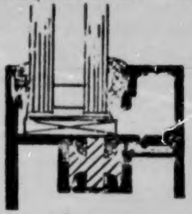
The thermal conductivity of glass is the normal limiting factor for the window So long as the frame has lower conductivity than the glass condensation is assumed not to affect the materials around the frame.

Material	Heat transmission per °F per hr. per sq. ft. (U)
Sheet glass	1.10 (average)
Double glazed 3/16" air space	.65
Double glazed 1/4" air space	.62
Double glazed 1/2" air space	.57

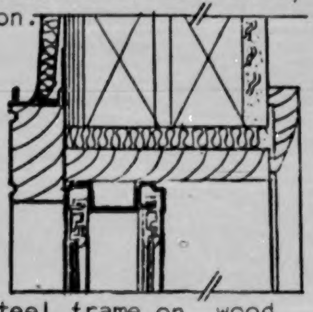
Thus wood frames over 2" thick have as much or greater thermal resistance than even the best double glazed units. But the metals have obvious problems.

In order to make metal frames perform satisfactorly it is neccessary to include a thermal break in the frame. This takes the form of a material of high thermal resistance, or low thermal conductivity.

The most commonly used materials are wood and plastic. Plastics are currently highly favored because of their ability to accept extrusion.



plastic extrusion in
aluminum frame



steel frame on wood
subframe

Research manufactures technical trade literature and perpare detailed plans and sections through three types of window.

1. Wood casement
2. Steel awning type window
3, Aluminum horizontal sliding

Draw these at the scale of 3" - 1'0"; include thermal breaks where necessary. All windows must be double glazed. Thermal breaks are required in windows whose frames are made of aluminum, steel, stainless steel, plastic, wood.

Check the appropriate materials.

Thermal breaks are required in windows whose frames are of aluminum, steel and stainless steel - and any other metal for that matter.

If you had included materials other than those above, review pages 135 through 138 before proceeding further.

Most users will tolerate faults in window performance so long as they do not leak water or air.

To achieve even this performance is not as easy as it would appear.

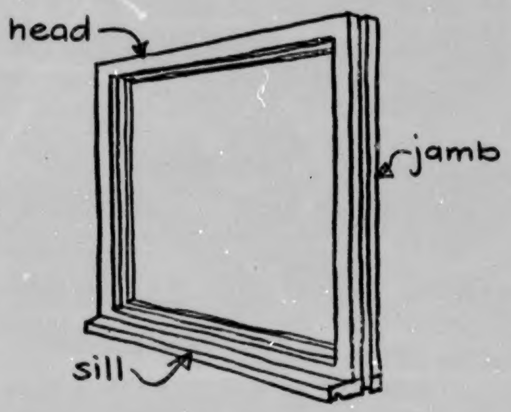
Two main aspects must be considered when evaluating window performance in connection with air and water leakage.

1. The window assembly itself
2. The connection between window and walls.

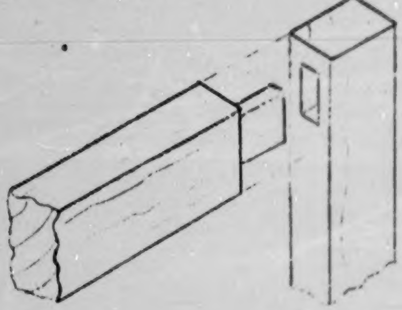
You will remember that in earlier discussions it was stated that in order for leakage to occur there are three factors involved.

1. There must be water present
2. There must be a hole through which it can move
3. There must be a force present to move it inward.

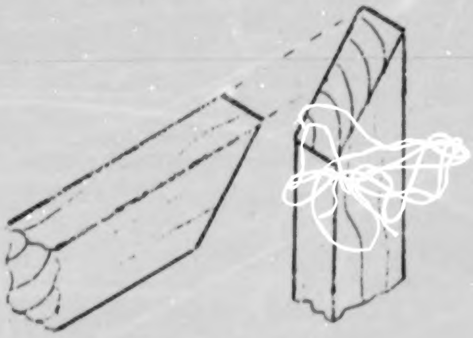
The window in its simplest form consists of the frame - a head two joints and a sill, the glass and a device to hold the glass in place.



The first point at which leakage can occur is at the junction between horizontal and vertical members. This joint is made either as a mortice and tenon joint or as a mitre.



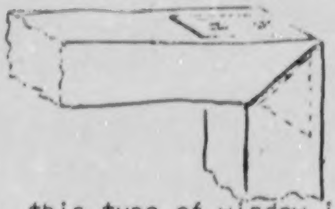
mortice & tenon



mitre

In the case of wood windows, leakage at these points rarely occurs, as the members are glued together and the whole assembly primed and painted.

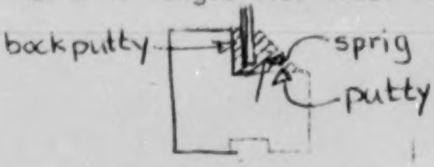
The problem is usually at its worst in aluminum windows; in the cheaper aluminum frames, the extrusions are accurately cut, mitred together, and fastened in this position by a metal angle bracket. This allows the possibility of leakage at the mitres.



Often to get over these problems, this type of window is caulked at the mitres, but caulking compounds break down with use. This method is used because it is cheap. In steel windows, and in better quality aluminum windows there joints are welded producing not only better weather proofing but a frame with superior rigidity. Leakage or condensation collecting in the hollow members of aluminum sections will result in leakage at the sill, despite the location of the water entry point.

The next leakage point occurs at the junctions between glass and frame. Several methods of making joints at this point are in common use.

The traditional method was to use putty - originally a mixture of white lead and linseed oil. The frame is back puttied, the glass bedded into this putty, sprigs (small nails) were used to hold the glass in position and then putty was applied at a 45° angle over these fastenings.

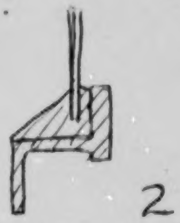


Materials have improved, but this basic method is still sometimes used.

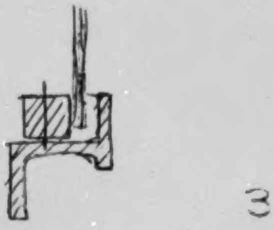
Unfortunately, although the material is resilient and waterproof and workable initially, even when protected by paint, as it must be, it rapidly dries out, hardens and falls away. This permits leaks to develop, and could even result in the glass falling out of its frame.

Currently methods can be categorized as sealants, tapes and gaskets in combination with removable glazing beads.

Rolled steel frames use sealants either with or without beads, as do wood windows.

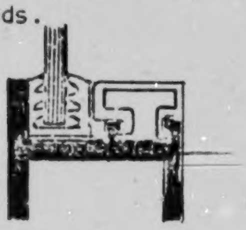


Without bead

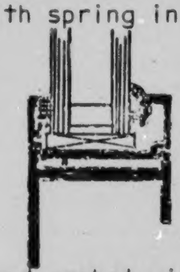


With screwed bead

Aluminum and pressed steel windows usually use gaskets or butyl tape or a combination of these with or without sealants, with spring in or screwed in beads.

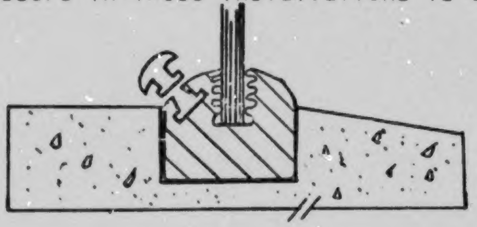


Snap in bead and gasket



tape and gasket with snap in bead.

The advantage of gaskets is that they are simply reused after glass replacement. But they must be preformed and held in place under pressure. Tapes are very satisfactory but must be replaced when windows are reglazed. They too must be held in place under pressure. Consequently a combination of tapes and gasket after installations of the window glass onto the tape and the bead provide the required pressure on the tape, allows part of the system to be reused and simplifies reglazing. Special purpose 'zipper' gaskets are also available. Gasket pressure in these installations is achieved by installing a spline.



Gaskets are generally expensive. Zipper gaskets are very expensive and are tolerable only on projects where large quantities of identical items are required.

The most likely place for a well designed window to leak is at

a) The head
b) The sill
c) The jamb
d) The glazing beads
e) The junctions of head and jamb
f) The junction of frame and glass
g) The junction of frame and wall

Check one.

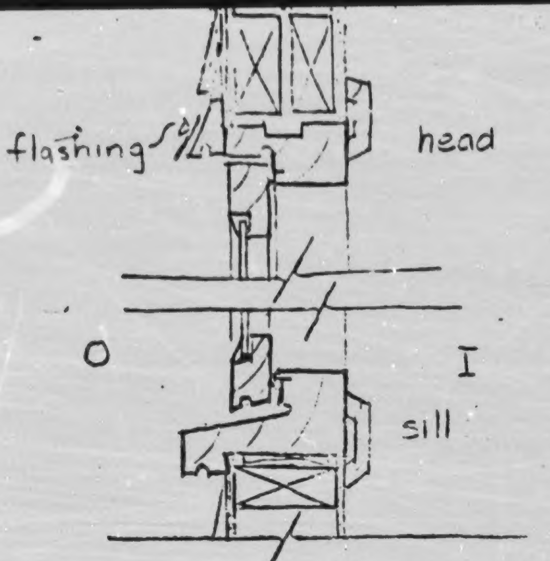
The most likely place for a well designed window to leak is at the junction of frame and wall.

The window itself can and is manufactured to very close tolerances under controlled conditions. The opening in the building is usually made of materials and under conditions where 1/2" is considered to be a superbly accurate tolerance. Under these circumstances the usual procedure is to bung up the gaps between window and wall with sealant. Unfortunately bunging up the holes rarely keeps wind and water out of a building for long. Nevertheless once one is aware of the problem, design skill can be exercised to reduce the possibility of leakage at this point to an absolute minimum.

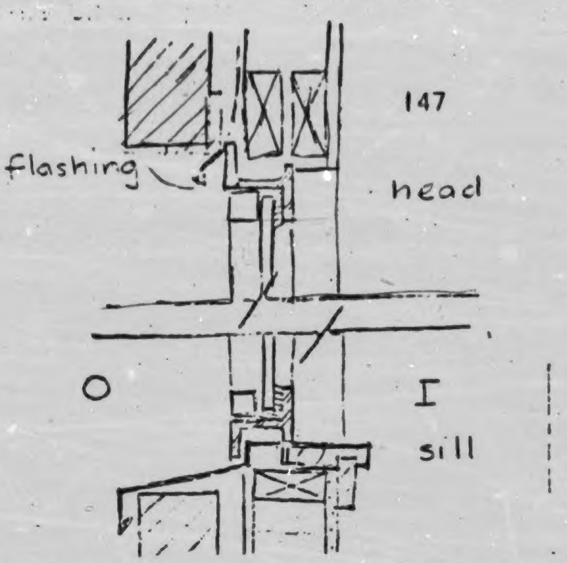
To depend upon a sealant alone as a waterproofing seal is dangerous. The best solution to the problem is to design the junctions so that it is waterproof without the use of sealants, and to use the sealant as an air seal.

Based upon your understanding of the "rain screen" principle as previously discussed when we examined walls and roofs can you sketch methods of making the wall/window junctions proof to rain entry without the use of sealants?

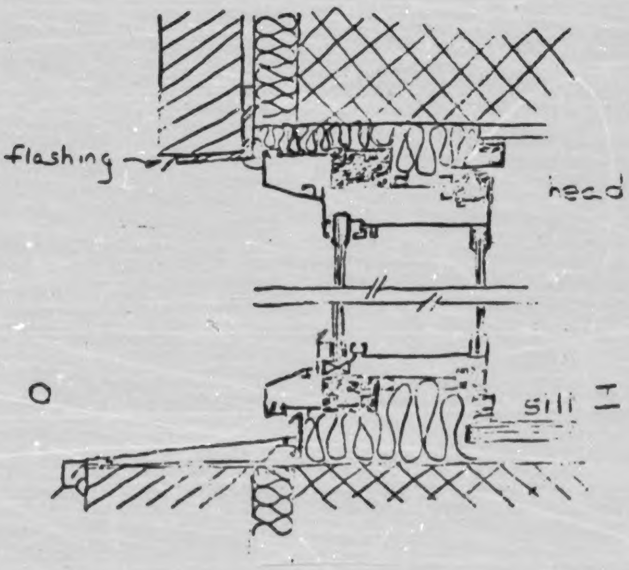
Record your solutions below and on the back of the preceding page if necessary.


flashing
head
O
I
sill

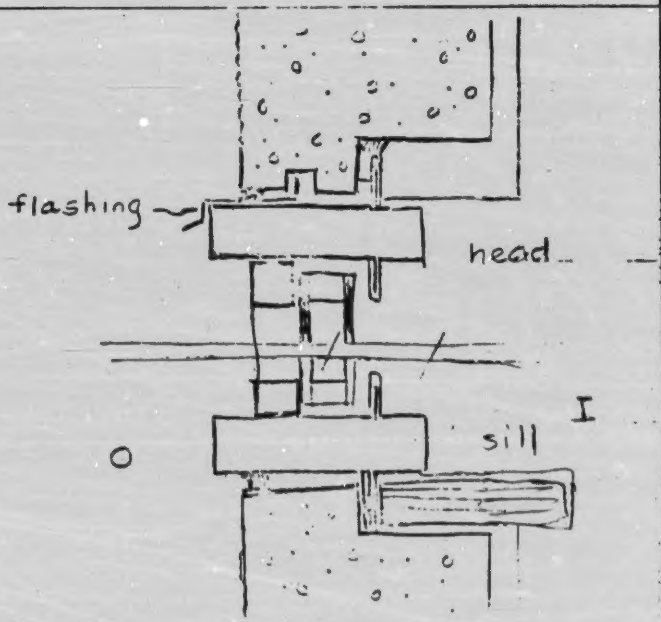
Wood casement in studwall


flashing
head
O
I
sill

Steel frame in masonry veneer.

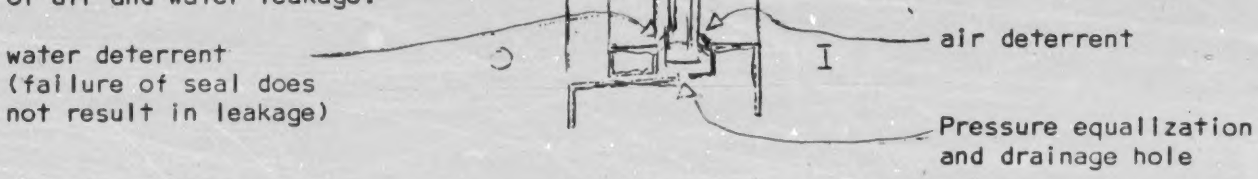

flashing
head
O
sill
I

Aluminum frame in masonry


flashing
head
I
O
sill

steel frame in concrete

The sketches above illustrate some ways of achieving the desired result. However, each building design produces its own problems. The connection details must be carefully considered at the design stage so that the influence of differing materials is adequately resolved. In fact in order to produce an entirely satisfactory window, the use of sealants must be accepted. The stetch below indicates the essential principles of frame constructions for satisfactory control of air and water leakage.


water deterrent
(failure of seal does
not result in leakage)
O
I
air deterrent
Pressure equalization
and drainage hole

Examine manufacturers technical literature, and prepare sketches based on this research demonstrating effective use of the principle of pressure equalization in frames as applied to two windows, one each of aluminum and steel.

The optimum location for a sealant in a window component is

a) at the outside face of the component

b) at the inside face of the component

c) at both inside and outside faces of the component.

Check I turn to page 149.

The optimum location for a sealant in a window component is at the inside face of the component.

The reasons for this are many, but the two essentials are:

1. The sealant is located in a position where temperature variation is at a minimum, and therefore the material is not called upon to respond to extreme temperatures or movement induced by these temperature changes.

2. Placing the sealant at the inside face prevents the movement of warm moist inside air into the cold parts of the wall, and thereby reduces condensation on the frame and in the wall.

Unfortunately it is not always possible to locate the sealant in its technically optimum position, but even so satisfactory service can be obtained by careful design based upon an understanding of the material.

Satisfactory sealant joints are achieved by using

a) as much sealant as possible

b) as little sealant as possible

c) an even bead of sealant

d) a carefully controlled amount of sealant

e) a sealant bead of controlled shape

Check the appropriate statements

Satisfactory sealant joints are achieved by using a sealant bead of controlled shape.

This type of sealant is gun applied. It is a viscous liquid that curves to an elastic material of high extensibility combined with good cohesive and adhesive abilities. In designing joints to receive this type of elastomeric sealant.

Certain basic principles must be adhered to in order to achieve satisfactory performance.

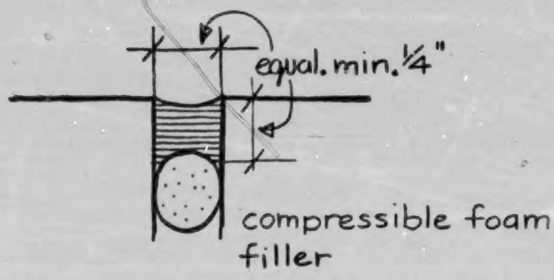
1. Although the shape of the joint neccessarily changes, its volume remains constant; which means that the geometry of the joint responds to movement.

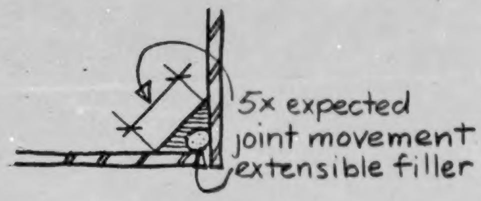
2. Because the thicker the bead depth, the greater the force required to extend it, deep beads have become prone to tearing away from the material to which they are intended to adhere.

3. Too shallow a bead will result in rupture of the seal itself.

4. In order to prevent complication of stresses, a sealant should only adhere at opposite surfaces.

The size of the joint is dependent upon the relative movement of the materials and components it connects but the sketches below embody the basic principles.





Butt joint joint 5X expected movement

Corner bead

Note that the fillers ensure that the cross section depth is less than the adhesive depth and that the joint depth is controlled by the placement of the filler.

An aluminum box section window frame is to be set in a cavity wall. Prepare a detail of the window wall interface showing the location and shape of the sealant joint a) on the outside face of the assembly b) on the inside face.

Assume that the total movement to be accomodated is 1/8".

It should be apparent that components cannot be fitted together without tolerance sufficient to permit movement without causing deformation of the component itself. Where opening windows are used, a gun applied sealant cannot be used to achieve air and water seals.

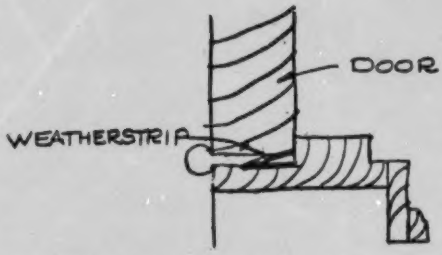
Resort must be made to weatherstripping.

Weatherstripping must permit easy opening of the window or door, but must achieve a tight seal when closed. It is usual to rely upon compressing the weatherstripping to achieve this.

Several materials are used for this purpose:

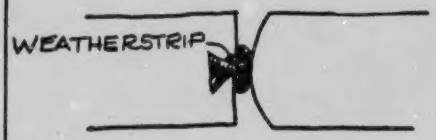
1. Metals (thin bronze, copper, stainless steel
2. Fabrics (wool or acrylic pile) felt
3. Plastics (Vinyl polyethylene, poly urethane
4. Rubber

1



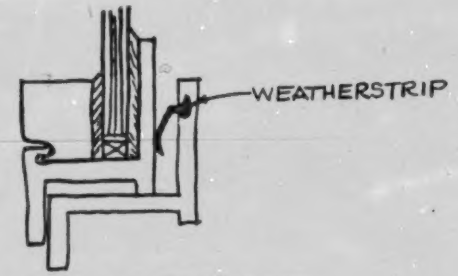
TYPICAL METAL WEATHERSTRIP

2



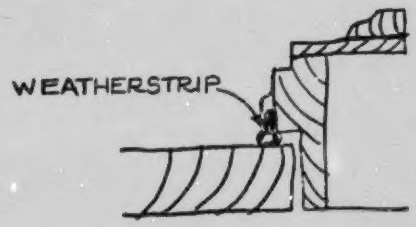
WOOL PILE

3



TYPICAL NEOPRENE

4

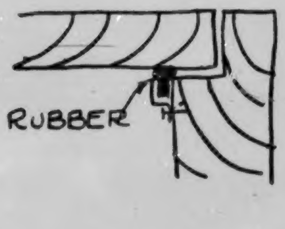


RUBBER OR PLASTIC

Many more sophisticated weatherstripping details can be found in textbooks and in manufacturers literature but the principle is the same: Compressing a gasket to form a weather tight seal.

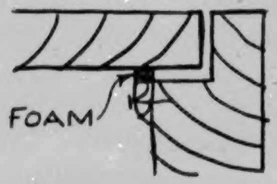
Doors use exactly the same principles. Usually, unless special purposes dictate, weatherstripping is applied to outside doors only. In order to control passage of sound air or light, however, inside doors may be weatherstripped as well. The jambs and heads of doors are simply handled.

1



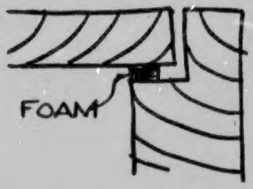
HEAD OR JAMB

2



HEAD OR JAMB

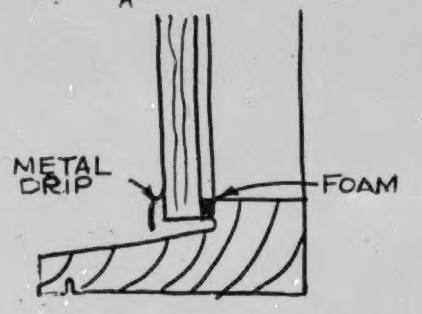
3



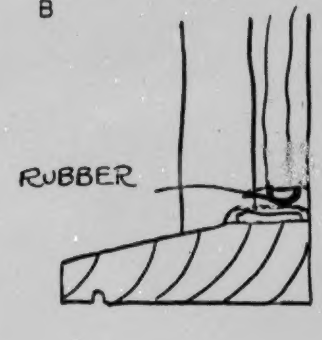
HEAD OR JAMB

The cill, however, is another matter, as usually it is desirable for good clearance to be provided for floor finishes etc. Some methods of providing a weathertight seal are shown below.

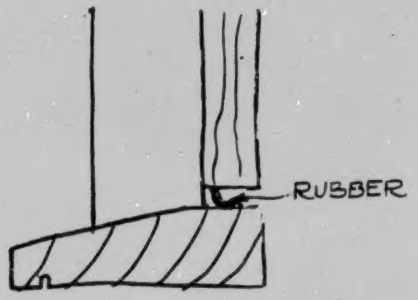
A



B



C



Once again the same principles are used to provide satisfactory performance.

The principles embodied in the sketches on p. 154 are

a) Use of gravity to promote drainage

b) Compression of gasket to provide air tightness

c) Use of tight fit to avoid capillarity.

Check appropriate statements

(c) is incorrect. Close fit will not avoid but promote capillarity. For demonstration of the mechanism of capillarity, see experiment in construction lab.

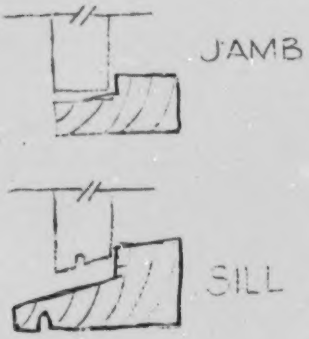
The use of gravity to assist in drainage comvined with a tight weather seal at the inside face is sometimes known as "two stage weather-tightening". The technique is deceptively simple as it requires that elements be designed specifically to handle one conditon at a time.

Draw at the scale of 1 1/2" - 1'0" a detail through a solid external door and frame, which embodies the principles of two stage weather-tightening.

In order to undertake this task successfully you will need information on types of doors and frames.

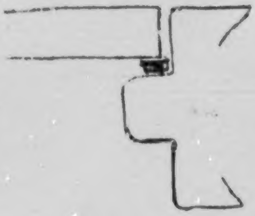
Doors are classified as flush, panelled, or glazed, and may be constructed of wood, steel or aluminum, as may be frames.

1



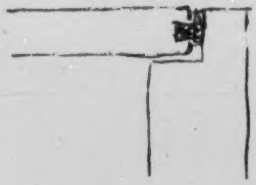
Wood

2



Steel

3



Aluminum

The above are a) interior b) exterior door frames
If you checked a) turn to page 159
If you checked b) turn to apge 157.

The following experiment must be undertaken in the Construction Lab

Intent

To note the amount of rise of water relative to the spacer between two similar materials.

Theory

Capillarity is a form of surface tension between the molecules of a liquid and those of a solid. When the adhesive force is stronger (capillary action) the liquid will tend to rise above mean level at the points of contact with the solid.

Equipment

Tray, two pieces of pane glass, glass holder, thin spacer, thick spacer.

Method

1. Add water to the tray to about 1/2" on glass. (Observe rise between the two pieces of glass).
2. Now take the two pieces of glass out and dry.
3. Place the two pieces of glass with the thin spacer back in tray.

Conclusion

Request report on methods of producing answer to problem.

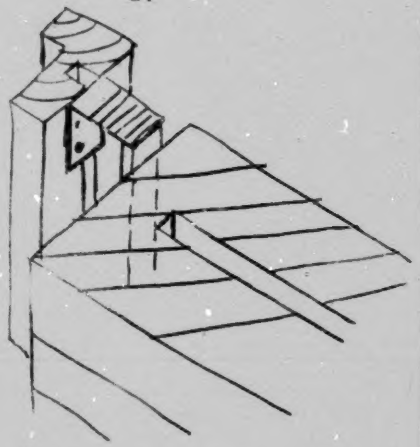
3/156

FJE:bdr

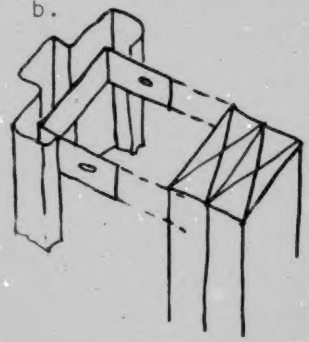
The frames shown could be used on internal doors but are usually used on exterior doors. As always the major problem is to achieve a satisfactory junction between frame and wall. It is equally important to ensure that the frame is firmly fastened to the structure. Doors frequently receive considerable abuse and thus if frames are not fastened securely to the structure insightly damage can result which can lead in turn to unsatisfactory performance and even failure.

Normally three frame anchors are used for each jamb (6 per frame) in the case of frames to dissimilar materials. For example wood frames in a masonry wall (a) steel frames in a stud wall (b) or steel frames in a masonry wall (c)

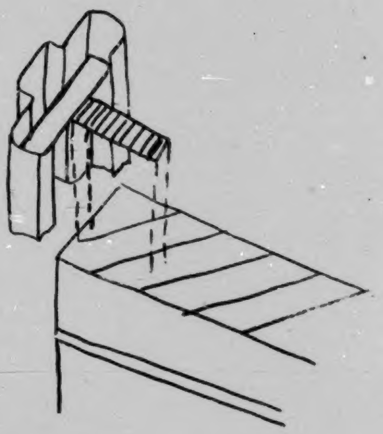
a.



b.



c.

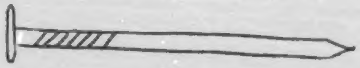


Naturally wood frames are simply fastened to studs with finishing nails, so that the head can be driven below the surface of the frame, and the hole left can be filled. Doors are fastened to their frames by way of hinges which are known as butts. These are screwed to frame and door in order to ease installation and removal.

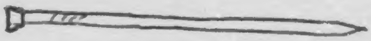
Internal doors are usually of light weight construction and therefore use only two hinges or, expressed in building trade terminology, one pair of butts. For heavier and exterior doors 1 1/2 pairs (or 3 hings) per door or leaf are used. Unless specifically requested, all hinges, or butts are supplied with a loose pivot pin, which simplifies even further the business of hanging doors, but equally results in making life easier for the thief as well. Thus for exterior or secure-interior doors fixed pivot pin hinges should be used.

Hinges can be obtained in a wide variety of materials, qualities and designs. The ordinary hinge uses plain bearings, more expensive hinges are provided with roller bearings.

A. This is a ______________ nail
(common) (spiral) (finishing)



B. This is a ______________ nail
(common) (spiral) (finishing)

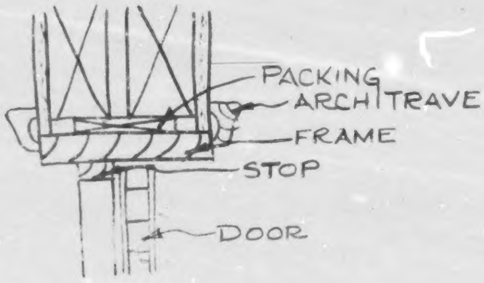


(Fill in appropriately)

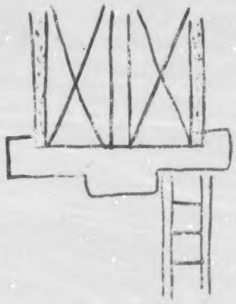
A was a common nail used in general rough carpentry. It provides a strong joint, the large head reduces the risk of pulling.

B is a finishing nail. As its name implies it is used in finishing work. That is work that is visible when the building is finished.

An internal door frame does not require a sill, as no attempt has to be made to maintain differing climates between rooms in normal circumstances. It is also usual to arrange for floor finishes to be at the same level, despite their thickness to avoid the possibility of a change in level causing danger. Internal door frames can be very simple:



Wood frame (typical)

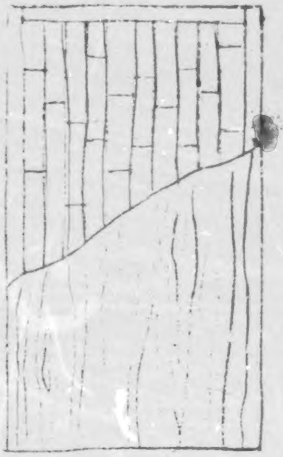


Steel frame typical

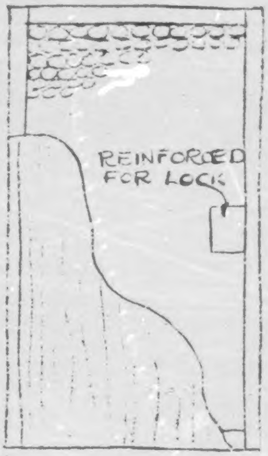
In the sketches above, the head of the frame is shown only, as the jambs are identical. Only the rough framing, which is not a part of the door frame varies. The rough opening in the stud wall (is) (is not) the same size as the door opening.

Delete the inappropriate words.

The rough opening in the stud wall is not the same size as the door opening, as the prepared space must not only provide room for the door and frame, but must also allow room to make final adjustments to the locations and plumbness (or verticality) of the frame. The amount of tolerance provided, varies with the type of frame, and in fact metal door frames are often "built in"; that is, the frame is erected first and the wall built around it. However, the wood door frame is rarely if ever constructed this way. A good rule for arriving at rough opening size is to take door width + 2X nominal frame thickness + 1/2", for the width, and door height + nominal frame thickness + 1/2" for the height. This is for a single leaf swing door, for double doors the rule must be modified to take account of the extra leaf and additional clearance. This will usually amount to the door width + 1/4". Packing, or shims are inserted between studs and finished frame to take up excess clearance. The most popular door at the present time is the flush door. It may have either a hollow or solid core. A solid core door costs between 3 and 4 times the cost of a hollow core door.



Solid core door



hollow core door

Standard door sizes
Hollow core: 1'6" - 3'0" wide in 2" increments X 6'8, 6'8", 7'0" high (interior)
Solid core: 2'4"-3'6" wide in 2" increments X 6'8", 7'0" high (exterior)
Available 1 3/8" and 1 3/4" thick

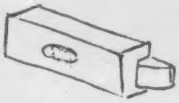
A flush hollow core door is (heavier) (lighter) than a solid core door and (should) (should not) be used as an external door.

delete inappropriate words.

A flush hollow core door is lighter than a solid core and should not be used as an external door. The hollow core door because of its lighter construction deteriorates rapidly if exposed to the weather and is unable to stand as much abuse. In addition its security value is limited, particularly due to the method used to provide reinforcement for the lock installation. See sketch on page 160. Locks, bolts, door handles, door closer, latches, hinges kickplates and so on all come under the heading of hardware. The subject of hardware has become so complex that it has given rise to a group of people who offer a service to the building trade as hardware consultants. In order that you have some idea of hardware, and so that you can extend your knowledge from a basis of understanding you should be familiar the terms used to describe the various items.

A latch set has no provision for locking with a key.

A lock set has provision for locking with a key, but does not neccessarily have a bolt.



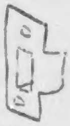
A rum latch, rim lock or rim dead lock are designed for surface mounting on the door.

A mortice latch, mortice lock or mortice dead lock is recessed into the thickness of the door.

A knob set consists of two knobs and a spindle, usually square.

A lever set consists of two levers and a spindle, usually square.

A striker plate, or receiver, is a plate attached to the door frame to receive the latch, bolt or both.



A night latch, which may be rim or mortice, is a lock operable by key on the outside and knob on the inside. It is usually provided with a snib so that the latch can be held in the open or retracted position during the day.

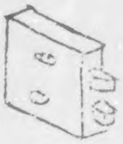
Kickplates are approximately 10" high, and protect bottom surface of doors from damage.

Mop plates are used in the same location but are only 4" high.

Push plates and pull plates' function is obvious.

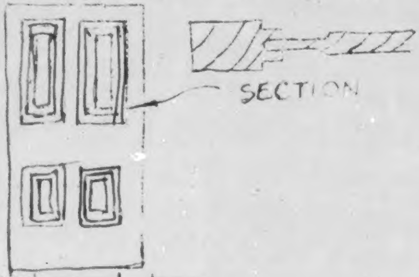
Door closer, usually hydraulic damped can be mounted on the surface or concealed in the head frame or floor.

A dead lock incorporates a sliding bolt in addition to a latch.

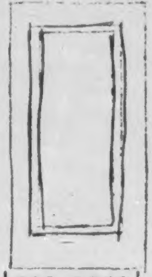


Make sketches of each of the items mentioned above.

As well as flush doors, wood doors are often panelled, or glazed.



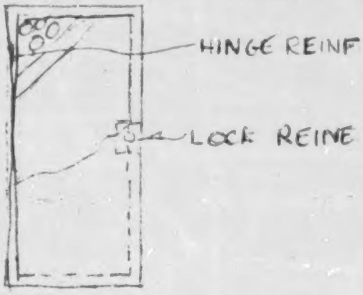
Wood panel door



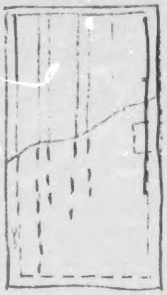
glass panel door

Sizes: height 6'8", 7'0"
widths 2'4", 2'6", 2'8"
2'10", 3'4"
thickness 1 3/8", 1 3/4".

Doors are not only available in wood, but in other materials as well as combinations of these. Examples are steel doors:



Styrene foam core
Steel door

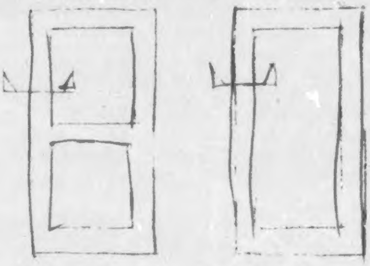


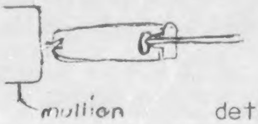
Steel stiffened
Steel door

glazed panel
steel door

A Kalamein door is a solid core wood door clad in steel. This type of door, steel doors and some wood doors can be obtained certified as to fire resistance. In certain locations fire doors must be used. Specific regulations will be found in the National Building code. Although doors are made in stainless steel, bronze and other expensive metals, these are special doors, and the last metal type we will consider is the aluminum door.

Aluminum doors are used for appearance, and are almost inevitably glazed.





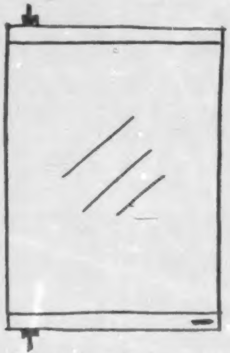
detail of aluminum door

Aluminum doors are most frequently used as exterior doors, and in public places in order to provide fire excape doors must be fitted with panic hardware - these are devices which permit doors to be simply opened by pressing on a bar from the inside. A key is usually use to gain access from outside. Doors may be glazed with ordinary or wired glass.

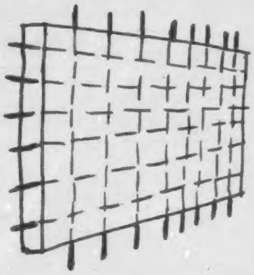
Glass is available in tremendous variety. Once it was fairly simple to understand glass types. However, the broad categories are:

1. Sheet glass
2. Plate glass a) polished
   b) float
3. Cast glass
4. Toughened glass
5. Coated glass
6. Tinted glass
7. Wired glass

In doors, sheet and plate glass are used where a view through the door is required. Sometimes doors are made from toughened glass, in which case no frame is required around the glass. Where a door is used as a fire escape, then any glass used must be wired. Wired glass is not stronger than other glass, but if broken the wire prevents glass from falling.



toughened glass door



wired glass.

Wired glass must be used in

a) All external doors

b) Doors used as fire escape doors

c) Internal doors

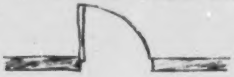
d) All doors in fire escape routes

Check appropriate statements

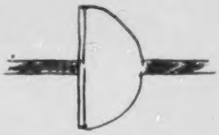
Wired glass must be used in all doors in fire escape routes whether inside or outside.

Specific requirements for doors and exits are described in Part 3 of the National Building Code.

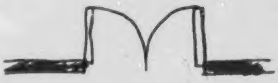
Conventions for indicating the location and operations of doors must be used on drawings.



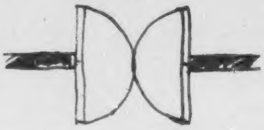
single swing door



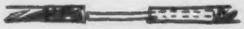
double swing



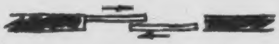
double doors opening one way only



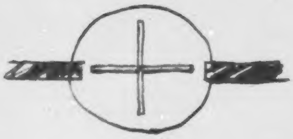
double doors, double swing



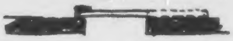
sliding door in pocket



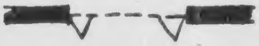
double sliding doors



revolving door

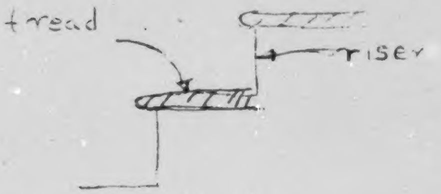


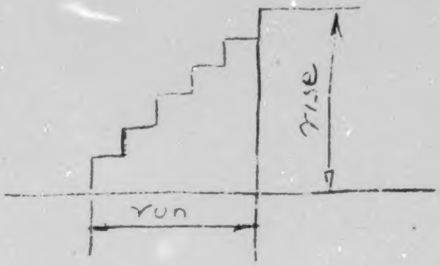
surface sliding door

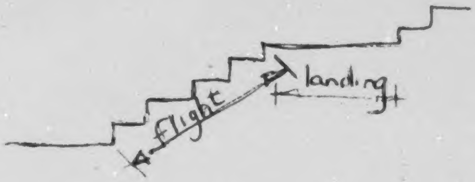


sliding/folding door

In order to travel from one level to another in a building stairs must be used. Other devices such as elevators, escalators and ramps are also used, but they do not obviate the use of stairs. Comfort and safety in using stairs is very important. Several formulae have been developed to assist in designing stair dimensions, but first you must understand the terminology.





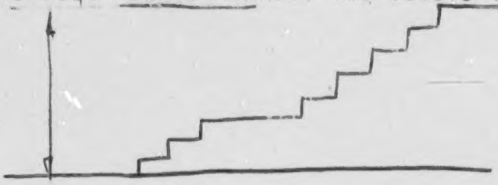


In order to arrive at an acceptable tread the following rules are used for interior stairs.

I Riser + I Tread = 17" - 18"
or 2 Riser + I Tread = 24 - 26"
or I Riser X I Tread = 70 - 75

The size of a tread is the size without the nosing. In order to ease the use of stairs it is best to inclued a nosing of I" - I I/2". The minimum that should be used is 5" and the maximum 8". Between 6 I/2" and 7 I/2" is most comfortable for the average person. Stairs designed exclusively for the very young should be sealed down in terms of both treads and risers

A stair is required to connect two levels in a building.

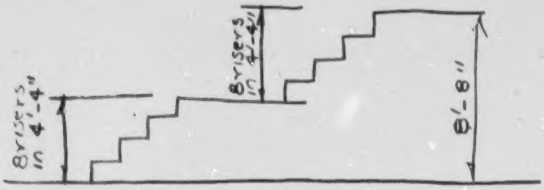


A landing is required halfway between levels, approximately. What should be the tread and viser dimensions?

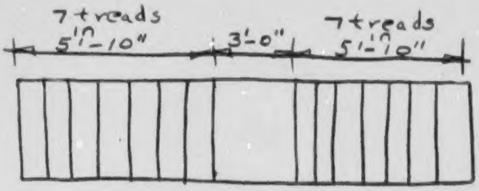
a) 6"R X 12"T b) 7"R X 11"T c) 6 1/2"R X 10"T
d) 7 3/7" rise 11 1/2"T e) 8 2/3"R X 10"T

Check the appropriate selection.

Only C and D are appropriate, as only these give the right proportions of tread to riser and fit exactly between floors and landing. Each rise and tread in a stair should be exactly the same size, otherwise the user can trip and fall in either direction. In providing directions on a drawing as to rise and run, the information will be provided in a different manner as shown below.

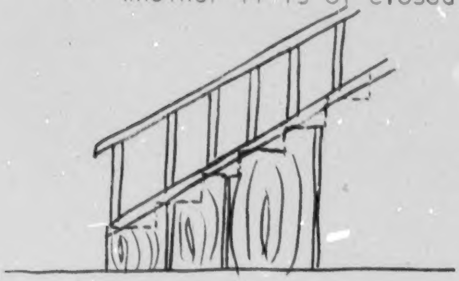

8 risers in 4'-4"
8 risers in 4'-4"
8'-8"

Section

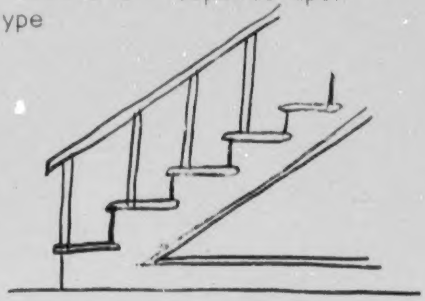

7 treads in 5'-10"
3'-0"
7 treads in 5'-10"

Plan

The detail construction of a traditional wood stair depends upon whether it is of closed or open string type

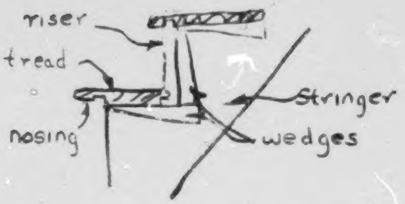


closed string

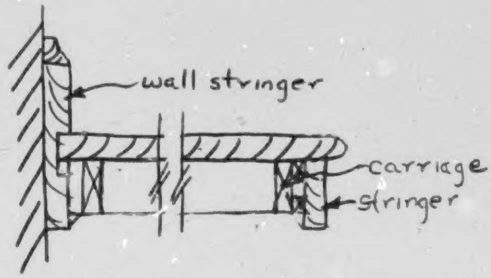


open string

In either case the basic stair is built up of carriages, usually two per stair, but sometimes three in a wide stair and strings, which are the finished sides of the stair.

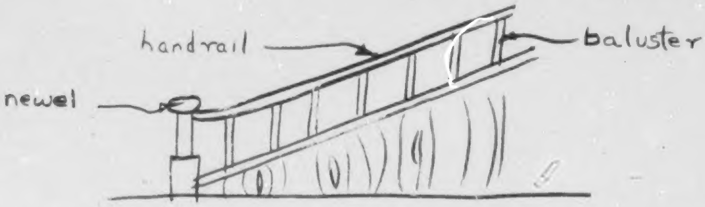

riser
tread
nosing
stringer
wedges

typical stair long section


wall stringer
carriage
stringer

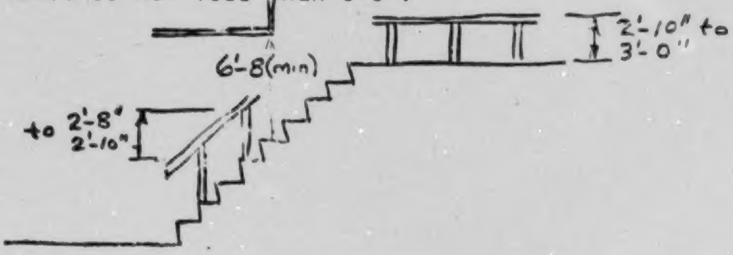
cross section

In addition to a surface on which to walk, a device is required to prevent people falling off the stair - this is the balustrade - which consists of the components shown on the sketch below.

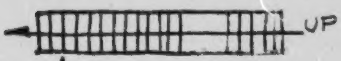

handrail
baluster
newel

Make an axonometric sketch of 1 flight of an open string stair.

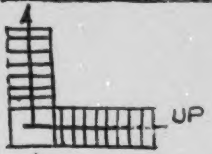
The height of hand rails on a stair should be 2'8" to 2'10" measured off the nose of the tread and at landing should be 2'10" - 3'0". The minimum width of a domestic stair is 2'8" clear. Clearance between obstruction and stair should be not less than 6'8".



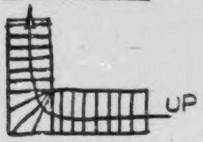
The configurations a stair may take consist of



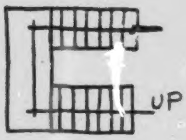
straight flight

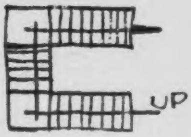


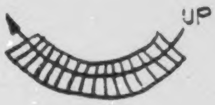
dog leg, without winders



dog leg, with winders



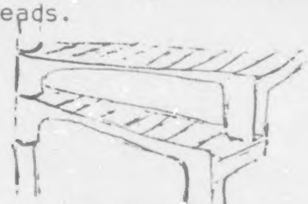




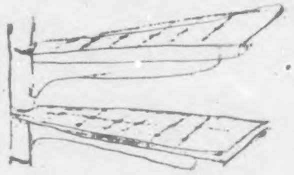
curves of various types

A spiral stair cannot be used as a primary means of escape, but it is an attractive and economic stair in terms of space occupied.

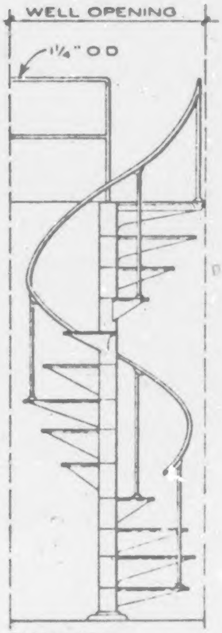
Spirals can be constructed from aluminum, steel, cast iron and concrete. All spiral stairs are built up from a central tube. The treads are either cantilevered off the central tube or use a combination of cantilevering and support from the previous tread, known as open riser treads.



Open riser treads



Cantilever treads



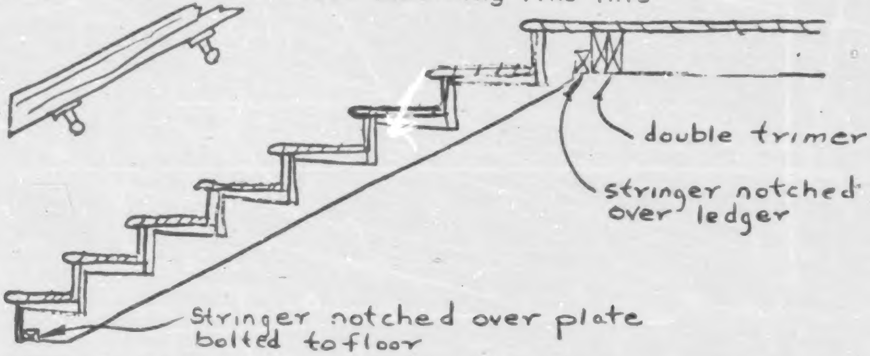
ELEVATION
CANTILEVER TYPE

Stair diameter	Treads in Circle	Riser Size	Head Room	Platform size	Well opening
3'6"	12	7½"-9"	6'9"	22"	3'8"
4'0"	12	7½"-9"	6'9"	25"	4'2"
4'6"	12 or 16	7"-9"	6'9"-7'0"	28"	4'8"
5'0"	16	7"	7'0"	31"	5'2"
5'6"	16	7"	7'0"	34"	5'8"
6'0"	16	7"	7'0"	37"	6'2"

If you refer back to p.   which covered the matter of framing openings in floors, and combine that information with information on stairs, you should how be able to produce a sketch showing the complete assembly. Attempt to draw a section showing a single flight wood stair connecting to a wood floor at top and onto a concrete slab at the bottom Scale not less than 1/2" = 1'0".

Turn to page 174 after you have completed this task.

The finished detail should look something like this


double trimer
stringer notched over ledger
Stringer notched over plate bolted to floor

Section through stair.

Not only must framed openings be constructed for stairs but also around fireplaces and flues. Although the use of electric heat is increasing, it is still more economical to burn oil or solid fuel for heating and most people enjoy an open fire in any case. Both furnaces and fireplaces require well designed flues in order to operate satisfactorily.

Headers and trimmers must be kept clear of chimneys and flues by a minimum of 2" in order to avoid the possibility of combustion taking place.

Chimneys are constructed of incombustible materials such as brick, concrete, stone or steel. Flue linings may be fire brick or hard glazed flue lining in a variety of sizes and sometimes steel.

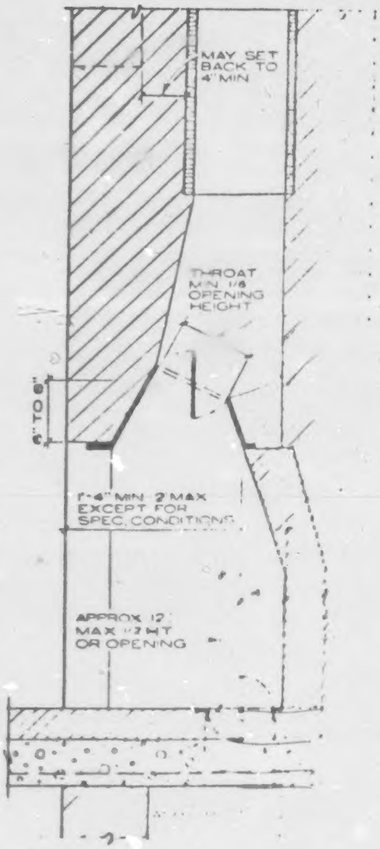
The fact that a flue works at all is based upon two simple facts.

1. Hot gases and air are lighter than cool air.
2. Air pressure reduces the higher one goes.

This second fact has implications beyond its application to flue design as it is this that is the cause of a number of otherwise unexplained effects in multistorey buildings. For the moment it is sufficient to know that if a tube open at two ends is suspended vertically, there will be air flow from bottom to top. The longer the tube the greater the draft. Flues shorter than 15'0" frequently give unsatisfactory service.

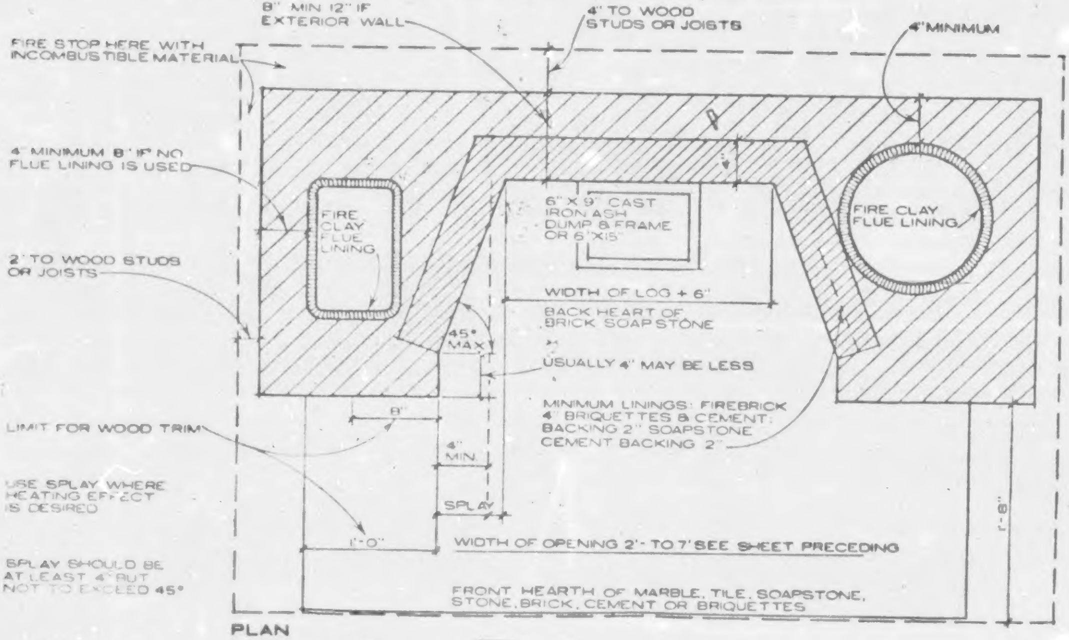
There is a positive relationship between fireplace face opening and flue cross sectional area. Flue area should be approximately 1/10th the area of the fireplace opening area, and never less than 1/12th at any time.

The sketch on this page clearly indicates the relationship and size of throat to fireplace.


MAY SET BACK TO 4" MIN
THROAT MIN 1/8 OPENING HEIGHT
6" TO 8"
1'-4" MIN 2' MAX EXCEPT FOR SPEC. CONDITIONS
APPROX 12" MAX 1/2 HT OF OPENING

SECTION
FIREPLACE WITH DAMPER

Flues should always be centered over the fireplace.


8" MIN 12" IF EXTERIOR WALL
4" TO WOOD STUDS OR JOISTS
4" MINIMUM
FIRE STOP HERE WITH INCOMBUSTIBLE MATERIAL
4" MINIMUM 8" IF NO FLUE LINING IS USED
FIRE CLAY FLUE LINING
6" X 9" CAST IRON ASH DUMP & FRAME OR 6"X15"
FIRE CLAY FLUE LINING
2" TO WOOD STUDS OR JOISTS
WIDTH OF LOG + 6"
BACK HEART OF BRICK SOAPSTONE
45° MAX
USUALLY 4" MAY BE LESS
MINIMUM LININGS: FIREBRICK 4" BRIQUETTES & CEMENT: BACKING 2" SOAPSTONE CEMENT BACKING 2"
8"
LIMIT FOR WOOD TRIM
4" MIN.
USE SPLAY WHERE HEATING EFFECT IS DESIRED
SPLAY
1'-8"
1'-0"
WIDTH OF OPENING 2'- TO 7' SEE SHEET PRECEDING
SPLAY SHOULD BE AT LEAST 4" BUT NOT TO EXCEED 45°
FRONT HEARTH OF MARBLE, TILE, SOAPSTONE, STONE, BRICK, CEMENT OR BRIQUETTES

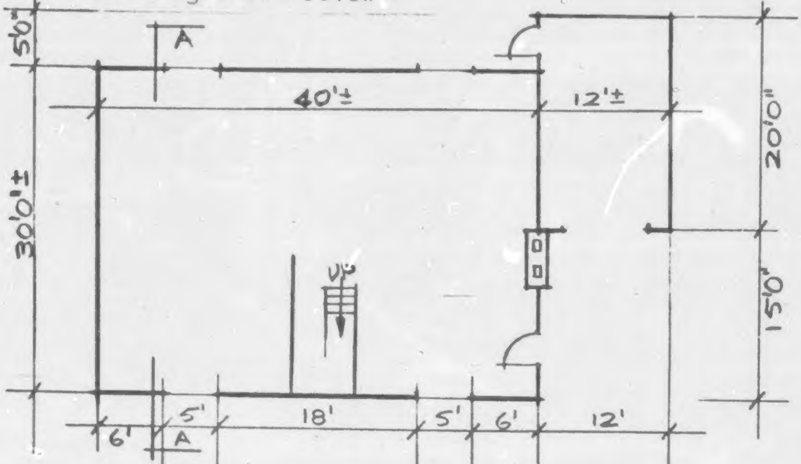
PLAN

Fireplace opening sizes

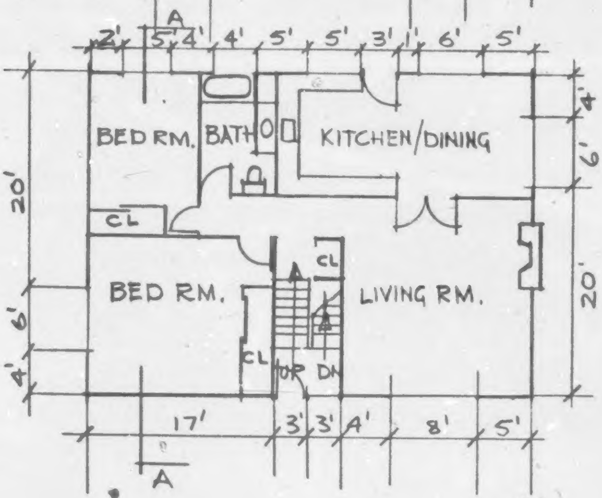
Width	Height	Depth	Splay	Req'd flue area	flue size round	fule size rectangular
2'0"	1'6"-1'9"	1'4"-1'6"	4"	min. 70 sq.in.	10"	8 1/2" X 13"
2'8"	1'9"-2'0"	1'6"-1'8"	4"	77 sq. in.	12"	8 1/2" X 13"
3'0"	2'0"	1'8"	6 1/2"	86 sq. in.	12"	12" X 12"
3'4"	2'0"	1'8"	6 1.2"	96 sq. in.	12"	12" X 16"
4'0"	2' 1 1/2"	1'9"	6"	120 sq.in.	15"	13" X 13"
5'0"	2'6"-2'9"	2'0"-2'2"	9"	198 sq.in.	18"	16" X 20"
6'0"	2'9"-3'0"	2'2"-2'4"	9"	260 sq.in.	20"	20" X 20"

At the top of the chimney, caps should be provided to reduce water ingress and to aid in combating downdrafts.

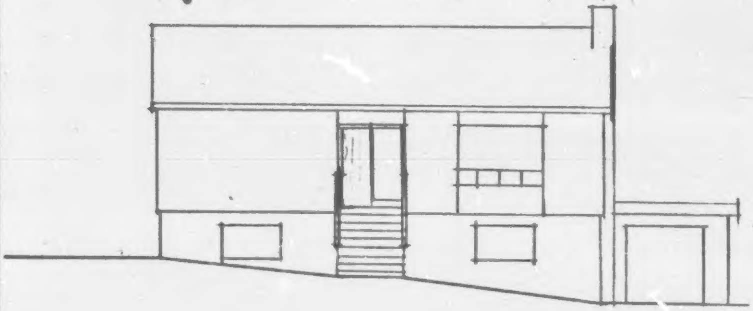
Prepare sketch plans and sections, elevations and details of the simple building shown below


5'0"
A
40'±
12'±
20'0"
30'0"±
UP
15'0"
6'
5'
18'
5'
6'
12'
A

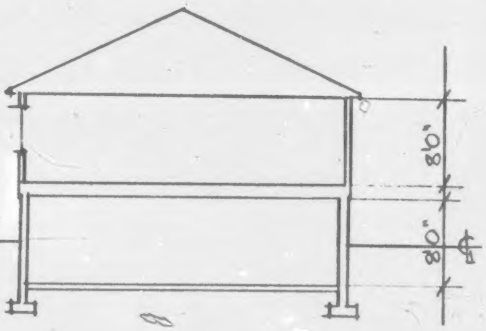
BASEMENT PLAN


A
2'
5'
4'
4'
5'
5'
3'
1'
6'
5'
BED RM.
BATH
KITCHEN/DINING
4'
6'
20'
CL
BED RM.
CL
LIVING RM.
20'
6'
4'
CL
UP
DN
17'
3'
3'
4'
8'
5'
A

FIRST FLOOR PLAN



ELEVATION



SECTION A A

SCALE APPROX. 1/16"=1'0" ALL DIMS. ±

With the completion of the last assignment you have completed volumn I of the programmed instruction construction program. By this time you should be aware of most of the principles underlying modern methods of construcing small buildings. These same principles apply to all buildings, although complexity and systems change and increase.

Thank you for using this book.

Please take the book and assignment to the instructor and at the same time request the test paper.

Following are a list of publications to which you may wish to refer for further information..

Architecture - Drafting and Design - Hepler & Wallach

Architectural Technology - G.H. Anthony

Building Construction - W.C. Huntington

Architectural Graphic Standards - Ramsey & Sleeper

National Building Code of Canada

Canadian Building Digest

Principles of Modern Building Vol. I & 2 - Building Research Station (U.K.)

Construction Materials & Processes - Don A. Watson

Construction Principles Materials & Methods - Schmidt, Lewis, Olin.

APPENDIX

Nailing for Framing, Sheating and Subflooring.

Canadian Building Digest (21) I
(Cavity Walls)

Canadian Building Digest (39) II
(Solar Heat Gain Through Glass Walls)

Problems of Decay III

Canadian Building Digest (111) IV
(Decay of Wood)

SHEATHIING AND SUBFLOOR ATTACHMENT

Element	Min. Nail length, in.	Min. Staple Length, in. (3)	Min. no. or max. spacing
5/16 and 3/8 in. plywood or particleboard	2 (1)	1½	6 in. o.c. along edges and 12 in. o.c. along intermediate supports
½ in. to ¾ in. plywood or particleboard	2 (1)	2	
7/8 in. plywood or particleboard	2¼ (1)	N/A	
7/16 in. and ½ in. fibreboard sheathing	1¾ (2)	1½	
½ in. gypsum sheathing	1¾ (2)	N/A	
board lumber 8 in. or less wide	2	2	2 per support
board lumber more than 8 in. wide	2	2	3 per support
Column 1	2	3	4

NAILING FOR FRAMING

Construction Detail	Minimum Length of Nails (in.)	Minimum Number or Maximum Spacing of Nails
Floor joist to plate — toe nail	3¼	2
Woods or metal strapping to underside of floor joists	2¼	2
Cross bridging to joists	2¼	2 each end
Doubled header or trimmer joists	3¼	12 in. o.c.
Floor joist to stud (balloon construction)	3¼	2
Ledger strip to wood beam	3¼	2 per joist
Joist to joist splice (see also Table 9.23.13.A.)	3¼	2 at each end
Tail joist to adjacent header joist (end nailed) around openings	3¼ 4	5 3
Each header joist to adjacent trimmer joist (end nailed) around openings	3¼ 4	5 3
Stud to wall plate (each end) toe nail or end nail	2½ 3¼	4 2
Doubled studs at openings, or studs at partition or wall intersections and corners	3¼	30 in. o.c.
Doubled top wall plates	3¼	24 in. o.c.
Bottom wall plate or sole plate to joists or blocking (exterior walls)	3¼	16 in. o.c.
Interior partitions to framing or subflooring	3¼	24 in. o.c.
Horizontal member over openings in non load bearing partitions — each end	3¼	2
Lintels to studs	3¼	2 at each end
Ceiling joist to plate — toe nail each end	3¼	2
Roof rafter, roof truss, or roof joist to plate — toe nail	3¼	3
Rafter plate to each ceiling joist	4	2
Rafter to joist (with ridge supported)	3¼	3
Rafter to joist (with ridge unsupported)	3¼	see Table 9.23.13.A.
Gusset plate to each rafter at peak	2¼	4
Rafter to ridge board — toe nail — end nail	2¼ 3¼	4 3
Collar tie to rafter — each end	3¼	3
Collar tie lateral support to each collar tie	2¼	2
Jack rafter to hip or valley rafter	3¼	2
Roof strut to rafter	3¼	3
Roof strut to bearing partition — toe nail	3¼	3
2 by 6 or less plank decking to support	3¼	2
Plank decking wider than 2 by 6 to support	3¼	3
2-in. edge laid plank decking to support (toe nail)	3	1
2-in. edge laid plank to each other	3	18 in. o.c.
Column 1	2	3

CANADIAN
BUILDING DIGEST

DIVISION OF BUILDING RESEARCH • NATIONAL RESEARCH COUNCIL CANADA

CAVITY WALLS

by T. Ritchie

UDC 69.022.322

The term "cavity wall" is applied to a type of masonry wall construction in which a continuous air space or cavity is provided inside the wall. A cavity wall therefore is actually two walls separated by an air space, but joined by means of metal ties for structural strength. They are extensively used in European countries, particularly Great Britain, where they have been developed as a means of obtaining protection from penetration of rain through masonry walls. In recent years in North America many important buildings have been constructed with cavity walls.

This type of construction is by no means modern. Traditionally solid masonry was used to enclose buildings and support the loads of roof, floors, furnishing and occupants, but as long ago as the last century it was not unusual for Canadian builders to use cavity walls instead of solid masonry and many such buildings are still in use.

Advantages

The most obvious advantage of cavity walls over those of solid masonry is the possible reduction in the amount of masonry used in construction, but other advantages such as improved thermal insulation are obtained from them. If a 12-inch solid brick wall consisting of three bricks side-by-side is compared with a 10-inch cavity wall composed of two bricks separated by a 2-inch air space, it is found that even though the latter wall is 2 inches thinner than the solid wall it has slightly greater resistance to flow of heat through the wall (i.e. it has greater insulating value).

The most important advantage of cavity over solid masonry walls, however, is the positive protection against rain penetration which cavity walls can provide. In many buildings solid masonry walls have been used under severe conditions of exposure to wind-driven rain, and frequently under these conditions the result has been penetration of moisture through the masonry to the interior, producing "damp wall" problems. Cavity walls, on the other hand, do not permit rain penetration; by their design, water cannot reach the inside surface of the wall. When rain falls on a cavity wall it may penetrate the outer wall, but the water then trickles down the inner surface of the outer wall and cannot traverse the cavity. The base of the wall is provided with metal flashings that direct any water that has entered the cavity outward through openings (weep holes) provided for the purpose.

Construction of Cavity Walls

Cavity walls do not require special masonry units. Conventional ones are employed although metal ties instead of bonding units tie the masonry together. The outer part of the cavity wall is usually brick masonry. The inner wall may also be of brickwork, but it is often constructed of structural clay tile, concrete blocks, or plain or reinforced concrete.

When a cavity wall is constructed on a foundation wall it is essential that a properly-designed gutter be installed between the foundation and the wall. The metal flashing which forms the gutter is placed beneath the outer part of the wall, and is shaped so that it turns up behind the outer wall and is carried into a mortar joint of the inner wall. A typical arrangement is shown in Fig. 1.

NRC DBR OTTAWA SEPTEMBER 1961 | CBD 21

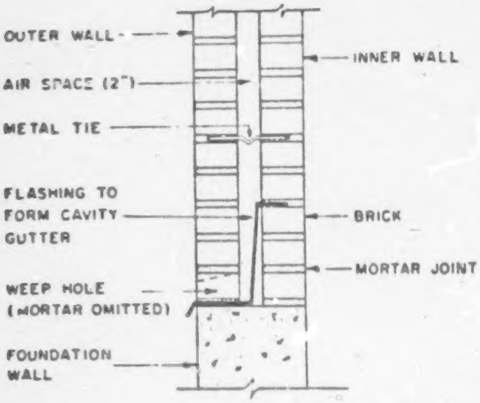


Figure 1 Typical Flashing Installation at Bearing Support of Cavity Wall.

The gutter collects water that moves down the cavity and must be drained. For this purpose mortar may be omitted from the vertical joints of the bottom course of bricks in the outside wall; usually every third joint along the course is left open.

During construction of a cavity wall the inner and outer parts are anchored by metal ties laid in the horizontal mortar joints. They are arranged in a definite pattern. It is essential that the air space be kept continuous and not bridged by mortar or other material that will allow water to pass across the cavity. To ensure this, wooden strips are usually used to collect mortar that drops into the cavity as the bricks are laid. They are placed on a row of ties and as they are pulled up to allow installation of the next series of ties, the collected mortar is removed from the cavity. Fresh mortar that may have fallen into the gutter at the base of the wall may be removed by a hosed stream of water.

Ties

It is the function of ties to anchor the two parts of the cavity wall together so that adequate strength may be obtained from the wall assembly. The tie must be strong in itself, and enough of it must be embedded in mortar to provide adequate anchorage. It should be at least 3/16 inch in diameter and should be bent at both ends to form 2-inch legs. In addition, it must be corrosion-resistant so that it is not destroyed by rusting in service; for this reason the use of non-ferrous ties is desirable. Copper and bronze are suitable materials, as is steel with copper welded to the surface or steel that has been galvanized by hot dipping. Uncoated steel ties or those coated with cement, tar or paint are not considered suitable for cavity walls. Corrugated metal strips of the type frequently used to tie veneer to a backing material should not be used in cavity wall construction.

Ties of several shapes are available, but that most commonly used is Z-shaped. Rectangular and U-shaped ties are also common (Fig. 2). Cavity wall ties are usually provided with a "drip" feature so that any water passing along the tie falls off at the drip into the cavity. They should not slope downward to the inner wall as this encourages passage of water across the cavity.

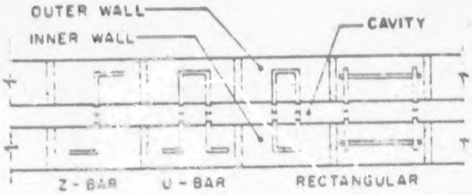


Figure 2 Shapes of Cavity Wall Ties.

Spacing of Ties

Provisions for cavity walls in the National Building Code of Canada require that ties be spaced vertically not more than 18 inches apart and horizontally not more than 36 inches apart. The ties must be staggered from course to course and each tie must extend at least 2½ inches into the masonry. Additional ties are required around openings in a cavity wall. These are installed not more than 12 inches from the opening, and are spaced less than 3 feet apart around it.

Structural Frame Buildings

A structural frame of steel or reinforced concrete members is usual in North America in the construction of buildings higher than three stories, and is often used for lower buildings as well. In this type of construction the frame rather than the masonry walls is used to support the loads on the building. Masonry merely shields the interior from the weather and resists the spread of fire.

Cavity walls have been combined effectively with structural members of frame-type buildings to provide excellent protection from weather. Frequently the outer surfaces of spandrel beams and columns are placed in the same plane and the inner part of the cavity wall is constructed flush with the surfaces of the beams and columns and anchored to them, while the outer part is carried on a shelf formed by a steel angle attached to a beam, usually at each floor level. A typical arrangement is shown in Fig. 3. The outer wall is anchored to the inner wall by metal ties. It is also anchored to the columns; in the case of concrete columns this may be done by dove-tailed anchors that fit into anchor-slots provided in the concrete members. Similar details are used when the structural frame is of steel members.

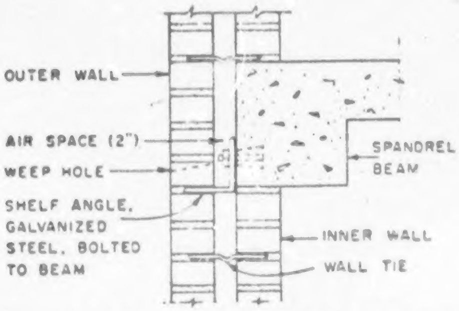


Figure 3 Typical Arrangement of Cavity Wall at a Spandrel Beam.

The shelf angle supporting the outer part of the cavity wall acts as a flashing to form a gutter. Where adjacent angles abut flashing must be placed over the angles to cover the joint. To drain the gutter, weep-holes are provided in the course of bricks resting on the angle by the omission of vertical mortar joints. The shelf angles should be galvanized steel in order to resist corrosion.

Door and Window Openings

Where a door or window is fitted into a cavity wall the continuity of the air space is broken, and care must be taken to prevent water from passing along the door or window frame to the interior. If a window is installed immediately beneath the shelf angle attached to a spandrel beam the normal flashing details for the shelf angle are sufficient to preserve the water-tightness of the wall along the top of the window. If openings are made elsewhere, however, a separate angle is provided as the lintel, and over the angle proper flashing must be installed to collect water moving down the cavity and weep-holes provided for drainage.

The sides of door- and window-frames must be designed so that water cannot travel along them to the interior. Diverter strips that project from the sides of the frame into the cavity are usually provided for this purpose.

Control Joints

The outer part of a cavity wall forms a relatively thin skin around a building and may be subjected to appreciable changes in temperature and moisture content, producing stresses which lead to cracking. In addition, the outer part of the wall may be affected by movements taking place in other components of the building. Experience in the design of cavity walls has indicated the value of providing vertical control joints in the outer part of the wall to accommodate these movements. It has been found that the corners of cavity walls are particularly susceptible to cracking when a structural frame has been used. Accordingly, a vertical control joint is usually provided in the outer part of the wall about 3 or 4 feet from the corner. In addition, to reduce the chance of cracking, the outer part of a cavity wall should not be tied to corner columns of concrete.

There is an even greater tendency for movement to take place in parapet walls than in the main walls of a building, and there is therefore a special need for control joints. Continuing the cavity upwards from the main walls into the parapet appears to be a desirable feature.

Cavity Insulation

In recent years special insulating materials have been developed for filling the air space of cavity walls in order to improve the thermal insulation value of the wall. The materials are pour-type insulations treated to render them water-repellent.

Since the main advantage of cavity walls — resistance to rain penetration — depends on keeping the air space free of anything that might form a "water bridge", it might be expected that filling the cavity would destroy its resistance to rain penetration. Laboratory tests have indicated, however, that this is not the case if specially prepared insulating materials treated to be water repellent are used.

Condensation

In the north-eastern area of the United States the performance of many cavity walls has been studied for several years. No special vapour barrier was installed in the buildings to control movement of water vapour from the inside to the outside, and there appeared to be no harmful effects of condensation in the walls. When high relative humidity is maintained in a building, however, and the outside air temperature is very low, as may be the case in many areas of Canada in the winter, there is danger of condensation of water vapour in the walls and of frost action. Under these conditions it seems wise to provide vapour barrier protection to cavity walls, particularly if the cavity contains insulating material.

Building Code Requirements

Special requirements for construction of cavity walls, particularly limitations on height, are contained in most building codes. The National Building Code of Canada 1960, for example, states that the maximum height to which a cavity wall may be built above its bearing support is 36 feet. For buildings taller than this it is necessary to provide intermediate bearing support so that the allowable height above the support is not exceeded.

The minimum thickness of a cavity wall is 10 inches, the cavity being not less than 2 nor more than 3 inches wide. For load-bearing cavity walls the National Building Code requires that the minimum thickness of the top 12 feet be 10 inches, that of the portion more than 12 feet but not more than 24 feet from the top, 12 inches, while that part of the wall more than 24 feet from the top must be at least 14 inches thick. As for solid masonry walls, lateral support, either horizontal or vertical, must be provided for cavity walls.

It is generally required by building codes that mortars of relatively high strength be used in cavity wall construction, probably because resistance of the thin outer part of the wall to lateral force is important. A general rule seems to be that mortar for cavity wall construction should be at least as strong as a mortar containing equal proportions by volume of lime and portland cement (1:1:5 or 1:1:6 by volume of portland cement : lime : sand) At the same time it should possess good workability and water-retention properties.

Conclusion

Cavity walls provide an important advantage over walls of solid masonry in that they can afford complete protection against rain penetration even when exposed to conditions of severe wetting by wind-driven rain. Under similar conditions rain leakage through solid masonry walls is not uncommon. There are three essential requirements for cavity wall construction: the cavity wall must have a gutter at its base to collect leakage water and drains to direct water out of it; the two parts of the wall must be anchored together with metal ties that are corrosion resistant and adequately strong; the wall must have a cavity free of mortar or other material that may form a water bridge across it.

Cavity walls have been used in many countries over a long period of time and have established their excellent performance record under widely varying conditions.

CANADIAN
BUILDING DIGEST

DIVISION OF BUILDING RESEARCH • NATIONAL RESEARCH COUNCIL CANADA

SOLAR HEAT GAIN THROUGH GLASS WALLS

UDC 697.132.3:69.022.32

by D. G. Stephenson

If the radiant energy from the sun that is constantly falling on the earth's surface had to be bought at ½¢ per kilowatt hour the daily bill would be the staggering sum of $10,000 billion. On a more comprehensible scale, the maximum intensity of solar radiation falling on a square foot of horizontal surface in the temperate latitudes is of the order of 100 watts; for vertical surfaces it is about 75 watts. There is, therefore, a large amount of energy falling on the outer surfaces of every building at certain times of the year – energy that can cause serious performance problems if it has not been fully taken into account by the designer. It is the purpose of this Digest to show the magnitude of the solar heat gain associated with glass areas in the different facades of a building, and to discuss the several ways that it can be reduced.

Intensity of Sunshine

The intensity of the sun's rays that penetrate to the bottom of the atmosphere depends on the clarity of the atmosphere and on the length of their path through it (i.e. the angular elevation of the sun above the horizon). The energy that is incident on a unit area of a particular surface depends upon the intensity of the sun's rays and the angle at which they strike the surface. The maximum intensity for a horizontal surface occurs at noon at the time of the summer solstice for all latitudes outside of the tropics. For example, the maximum insolation on one square foot of horizontal surface is 93 watts at Ottawa (latitude 45°N) and 88 watts at Winnipeg (latitude 50°N). At the winter solstice the corresponding figures for noon on a clear day are 39 watts and 29 watts respectively. (Multiply watts by 3.4 to obtain Btu/hr.)

The radiation that falls on vertical surfaces is, however, often of more importance in building design (because of windows) than the radiation on a horizontal surface. The orientation of a wall is an additional variable. A wall facing south at Ottawa receives a daily maximum of 45 watts/ft^2 at noon on June 22nd or thereabouts; but at the equinox the daily maximum has increased to 65 watts/ft^2; and the yearly maximum may be as high as 100 watts/ft^2 in winter if there is snow on the ground to reflect some sunshine onto the wall. East and west facing walls, on the other hand, receive their maximum irradiation in the morning and afternoon, respectively, when the sun's rays are more nearly perpendicular to the wall surface. The annual maximum for east and west facing surfaces at Ottawa is about 75 watts/ft^2. It occurs at midsummer approximately 4 hours before and after noon respectively (as indicated by a sun-dial). The magnitude of the daily maximum changes very little between midsummer and the equinox, so that the value of 75 watts/ft^2 is representative of the daily maximum insolation on east and west facades during the period from April to October.

Transparent Walls

When solar radiation falls on glass and other partially transparent material some of the incident energy is reflected, some is absorbed by the material, and the rest is transmitted to the inside of the building. For ordinary windows the absorption is quite a small fraction and transmission much the largest part. It is not always appreciated, however, that the reflection from the surface of glass varies considerably with the angle of incidence, i.e. the angle between the light rays and a line perpendicular to the surface. Figure 1 shows the variation of the reflection, absorption and transmission of solar radiation by a single sheet of ordinary glass. The noon values of the incident angles for a south wall at Ottawa are shown on Figure 1. They indicate that transmission will have a daily maximum value of 70 per cent of the incident radiation at midsummer and that this will increase to

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85 per cent at the equinox and to a maximum of 87 per cent at noon in midwinter.

It is easy to appreciate why a building designer should take great care to minimize solar heat gain when one considers the cost of the air-conditioning plant needed to remove it. It has been stated that the insolation on east and west facing walls can be 75 watts/ft^2 at the daily maximum during the whole period from April to October. The incident angle for these surfaces at the time of peak insolation is less than 40 degrees so that transmission is about 87 per cent for a single sheet of glass. One hundred square feet of ordinary glass in a west facade would, therefore, transmit 6.5 kilowatts to the interior of the building. All this energy must eventually be removed by the ventilating and air-conditioning equipment.

Fortunately all of the transmitted solar radiation does not immediately act to increase the cooling load; some is stored in the floor and internal walls, which absorb the radiation and are warmed by it. The maximum cooling load has been found[*] to be about 60 per cent of the maximum instantaneous heat gain for a modern multi-storey office building with 80 per cent of the exterior wall made of glass. Thus the maximum cooling load associated with the solar transmission through 100 ft^2 of ordinary single glazing in a west wall can be taken as 60 per cent of 6.5 kilowatts, i.e. about 4 kilowatts or just over 1 ton of refrigeration.

The cost of an air-conditioning system depends on the type of building and the type of system used, but it usually exceeds $1,000 per ton. This represents about $300 per ton for the central cooling plant with the other $700 for the distribution system. The increase in the cost of a building that can be attributed to the solar heat gain through a window depends, therefore, on whether or not the added heat gain increases the peak cooling load for the building. If it does, the full $1,000 per ton should be charged to the window; otherwise, a figure approaching the $700 per ton cost of the distribution system would be more appropriate. If the added light provided will result in a decrease in the use of artificial illumination, however, some credit may be allowed. Thus the initial cost of air-conditioning equipment required to remove solar heat admitted through an east or west facing window may add about $7/ft^2 of window to the cost of the building. There is in addition an annual operating cost for this equipment. The heat gain from heat conduction through an equal area of insulated opaque wall is less than 5 per cent of the transmission through the glass, so essentially all of the $7/ft^2 should be added to the cost of the glass to give an equivalent first cost of a window.

The corresponding figures for a window area in a south facing wall are:

at the summer solstice, a transmission of 70 per cent of the incident beam of 45 watts/ft^2, which gives an instantaneous heat gain of 31 watts/ft^2 at noon;

at the autumn equinox, a transmission of 85 per cent of the incident beam of 65 watts/ft^2 for an instantaneous heat gain of 55 watts/ft^2.

These figures show some of the advantages of orienting a building so that the windows are facing south rather than east or west; the maximum heat gain due to solar radiation transmitted through the glass is less and the maximum occurs at the end of the cooling season so that it does not coincide with the maximum cooling load due to ventilation. North windows, of course, have very small solar heat gains.

Control of Solar Heat Gain through Windows

The real cost of removing the heat that enters a building through the windows is so great that it is economic to spend considerable sums of money to reduce solar heat gain. The most obvious method is to use some form of shade to intercept the radiation before it even reaches the window. This can be done much more easily for south facing windows than for those facing east or west, since for the south facade the angle of incidence is large in summer and projections from the wall consequently cast long shadows.

Solar heat gain through a south facing window can be significantly reduced also by tilting the glass as shown in Figure 2. The energy falling on the window in this configuration is the same as would occur if the window were vertical and had a 1.4-foot projecting shade along the lintel. The tilted glass reflects 45 per cent of the radiation when the incident angle is 78 degrees, compared with 23 per cent when the glass is vertical. This difference in reflectivity decreases as the season progresses toward the winter solstice, and in winter the tilted and vertical windows transmit essentially the same amount of solar energy.

Reflectivity of glass can be increased by coating the surface with either a very thin metallic film or a film of dielectric material that has a high index of refraction. Sealed double glazing units are now available with a reflective coating on the inside surface of the outer pane. Their reflectivity depends on the angle of incidence just as for uncoated glass, but the

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[*] Stephenson, D. G. and G. P. Mitalas. An analog evaluation of methods for controlling solar heat gain through windows. Journal, American Society of Heating, Refrigerating and Air Conditioning Engineers, Vol. 4, No. 2, February 1962, p. 41-46. (NRC 6560)

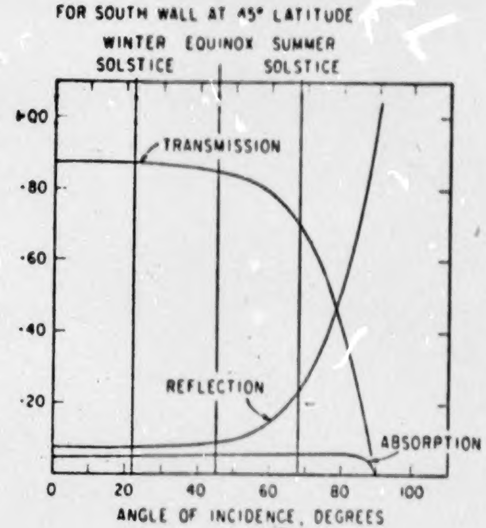

Figure 1
Absorption, reflection and transmission for single sheet of ordinary glass.

value at all angles of incidence is higher than for ordinary glass.

Blinds provide another method of solar control. A light coloured blind reflects some of the solar radiation and absorbs the rest. This causes the blind to heat until it is losing heat at the same rate as it receives it from the sun. If the blind is in the room, most of the energy it absorbs is added to the room's cooling load. If it is between the panes of a double window, however, some of the absorbed energy is transferred to the outside air and the room's cooling load is reduced accordingly. It is desirable, therefore, to use light coloured blinds and, if possible, to place them between the panes of a double window.

Heat absorbing glass is also widely used to reduce solar heat gain. Glasses are available that absorb over 70 per cent of the incident radiation so that transmission to the inside of a building is about 20 per cent when the angle of incidence is small and even less when it is large. Absorbing glass is not as good as these figures indicate, however, because the energy that is absorbed by the glass is dissipated to the surroundings on both sides of the window. The proportion of absorbed energy that is transferred to the inside depends on the relative magnitudes of the heat transfer coefficients at the inside and outside surfaces. If cool air is introduced into the room through a grill along the window sill more than half the absorbed energy is transferred to the room side. Thus, the use of heat absorbing glass may cause a higher maximum cooling load than occurs with ordinary glass because part of the absorbed energy is transferred to the room air very soon after it has been absorbed by the glass. Energy transmitted through ordinary glass is absorbed by the floor, walls and furnishings and released much later. The heat storage capacity of these objects tends to spread the cooling load over a considerable period of time so that the peak value is reduced.

The effectiveness of heat absorbing glass may be increased by using it as the outer pane of a double glazed window so that absorbed energy can be more readily dissipated to the outside air than to the room air. An even greater fraction of the absorbed energy can be rejected to the outside atmosphere if there is a free circulation of outside air through the space between the panes of the double window. The outer sheet of heat absorbing glass is then just a semi-transparent outside shading device.

Heat absorbing glass can sometimes be used to advantage for south windows if shading or tilting are unacceptable for architectural reasons. It has its best application, however, for east and west facing windows where effective outside shading becomes expensive and the simple expedient of tilting has no appreciable effect.

Large areas of glass in the outer walls of a building can cause undesirable glare in the space near the windows. Any method of re-

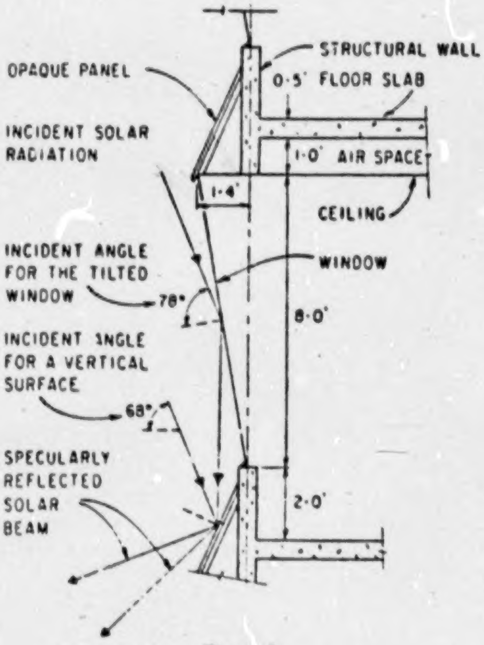

Figure 2
Schematic arrangement of a tilted window in a south facade.

ducing solar heat gain will also alleviate glare since approximately half of the total radiant energy from the sun is in the wavelength region of visible light.

Heat Gain through Glass during Fall and Winter

The foregoing discussion has been concerned with solar heat gain during the summer. It is also important to consider heat transfer through windows during the other seasons. Any building that has 50 per cent or more of its outside walls made of glass will have sufficient solar heat gain during some hours of the day in spring and fall to require cooling, even though the outside air temperature is well below the desired room temperature. During the dark hours of these same days there will be a substantial heating load because of the high heat loss outward through the glass. The need for cooling during what is normally considered the heating season means that the air-conditioning distribution system must allow for the simultaneous distribution of a heating and a cooling medium; and the building must be carefully zoned so that each area can have the heating or cooling that it requires. As this increase in the complexity of an air-conditioning system is mainly a consequence of the use of transparent walls its cost should be charged against the glass walls.

Glass areas have higher values of over-all heat conductance (U value) than do insulated opaque walls; and large areas of glass in the outer envelope of a building cause higher rates of heat loss during the long winter nights. A larger capacity heating plant is needed, therefore, for a building with extensive areas of glass than for one with walls containing conventional insulation. The net loss of energy through a wall is the difference between the loss by conduction to the outside air and the gain by transmission of solar radiation. This net loss during the winter months depends on the average outside air temperature, or the number of degree-days during the winter, as well as on the amount of radiation that falls on the glass. A double glazing of ordinary glass in a south wall at Ottawa, for example, has a slightly lower net heat loss for a whole winter than has a similarly exposed insulated wall. This small gain is probably offset in most cases by the air leakage through the cracks around a window. There is, therefore, practically no difference in Ottawa in the annual energy requirements for heating when a part of an insulated south wall is replaced by double glazing of ordinary glass. There is a higher net loss for other types of windows or for any windows in other exposures, the maximum, of course, being for north facing windows.

This simple analysis assumes that all solar heat can be used to reduce heating requirements. If a glass area is large it may be necessary at certain times to waste some of the available solar heat; to do otherwise would make the building uncomfortably warm.

Summary

Significant amounts of solar radiation are incident on all surfaces of buildings except the north wall. Solar radiation transmitted through unprotected windows or transparent walls causes a great increase in the cooling requirements of an air-conditioned building or high air temperatures in a building without cooling. Shading and other methods of reducing solar gain are beneficial for both cooled and uncooled buildings. The initial cost of the air-conditioning equipment necessitated by a window of ordinary plate glass can be greater than the cost of the window itself; and there is, in addition, an annual cost of operating the system to pump out the heat that the glass lets in. Both these costs should be included as part of the price that has to be paid when a building designer decides to use large areas of transparent materials in the envelope of a building.

Solar heat gain can be substantially reduced by orienting a building so that there is a minimum of glass in the east and west facades. Windows facing north have very little solar radiation incident on them; this is an advantage in summer, but results in increased energy requirements during the heating season. Solar heat gain through south facing windows can be controlled during the summer by outside shades or by tilting; if they are double glazed such windows do not increase the energy requirements for heating in the southern parts of Canada.

Where windows are deemed necessary in east or west facades the heat gain can be reduced by using double glazing, with the outside pane of heat absorbing glass; the effectiveness of such windows is increased by allowing a free circulation of outside air through the space between the panes. If sealed double glazing units are used a reflective coating on the inside of the outer pane is more effective than a pane of heat absorbing glass with the same light transmission. Finally, blinds can be used to reduce solar heating. They are more effective when located between the panes of a double window than on the room side of the window.

7) Hardware - In many homes these items are completely neglected and after a few years they jam or rust or otherwise become defective. A few minutes each month with a graphite spray or a can of special lock oil may delay renewal indefinitely.

8) Electrical - Periodic checks should be made of lamps and fuses to check for defects as lamp performance decreases rapidly immediately prior to failure. Exposed wiring should be checked for frayed insulation, and fittings checked for burns which indicate an overload problem or short circuit. It is a good policy to check the total house load every few years as, with the passage of time, one tends to forget that the circuits may originally have been loaded to maximum capacity before subsequent appliances were installed. If a house has more than eight light points or two power points per circuit then the system is overloaded and the circuits should be reorganized or the house rewired.

2) General Construction

The following comments apply to construction in general and are not classified according to either construction type or building type.

The order of presentation does not necessarily follow the proposed order of inspection, but rather according to material and its effect on the general maintenance.

WOOD

When selecting wood as a construction material, three main features must be considered from the point of view of maintenance.

Problems of decay;
Problems of finishing;
Problems of fire resistance.

This field, as can be seen, covers many sections of the inspection list but the cause of most of the defects listed will be either improper use of material, or incorrect installation of material.

Problems of decay

The word "decay" is used in its wide sense and is intended to cover the following:-

Molds and stains in wood;
Wood-destroying fungi;
Wood-destroying insects.

Moulds and Stains. Prior to installation in a building, molds and stains may not be very significant. They normally affect sapwood.

Molds rarely stain the wood to any depth and can usually be brushed off and the wood surfaced.

Staining is often caused through improper drying conditions and usually occurs in the sapwood soon after cutting. Main causes are bad moisture and temperature conditions, and sometimes improper stacking of lumber when air drying. The discolouration is often of blue-black colour and is sometimes referred to as "bluing"; it penetrates the sapwood and cannot be removed by surfacing or other treatment. Staining rarely affects the strength of the lumber for normal purposes, but it should not be used for work in which appearance is important.

When seen on inspection, it need not be noted unless the lumber is still in a saturated condition - this may indicate that the lumber (in a new building) was not cured and that shrinkage may take place causing defects to other components of the building.

Stained lumber should not be used in millwork externally because, if the wood again becomes wet, the staining fungi may start up again and affect the finish of the wood.

Wood-destroying fungi. These are the most serious problems in connection with wood in most areas, though in some areas insects are far more destructive.

Most of the rot caused by fungi is commonly misnamed "dry-rot". This is incorrect, as no really dry wood will rot.

The true dry-rot can be caused by one of several types of fungi with water-conducting strands. These fungi thrive on moisture and cause decay in wood by breaking down the fibre structure. A true dry-rot will only exist in a damp place with little or no ventilation and the elimination of these two conditions will stop the further progress of dry-rot, provided that all affected timber is removed and all non-combustible surfaces burned off with a blow lamp to kill any live spores that may exist. The surface should then be treated with a chemical preservative compound, and for safety, new timber installed should be similarly treated.

Most of the wet-rots that occur attack both sapwood and heartwood. The surface growths are usually fluffy or cottony; they are rarely powdery, as are some molds and some species of dry-rot. They consist of rootlike strands fanning out over the wood and are usually white or brown. In the early stages, the wood discolours but, as internal rot occurs, fruit-bodies may appear on the surface.

The fungi normally live off the wood, white fungi usually living off the lignin in the wood, and the brown fungi living off the cellulose in the wood.

Briefly, these are the facts behind wood destroying fungi. Methods are now described as to how fungus attack can be prevented in buildings and what steps can be taken after attack.

Precautions must be observed, firstly, when building, and secondly, when making repairs. When building, do not use unseasoned or infected wood; build in such a way as to prevent wood from becoming moist enough to decay, as all fungi need moisture to live. The following points should all be watched both in building and when maintaining a building.

1) Lumber which, of necessity, is exposed to the weather and moist conditions, should be rot resistant or treated to make it so.

2) Lumber should not be placed in contact with the earth - thus, mud sills should not be used.

3) Lumber must be well-ventilated, especially on lower levels or in roofs where leaks may occur.

4) Concrete must be allowed to dry fully before covering with a floor of wood.

5) Lower rails and sills of windows and thresholds of doors should be designed to prevent accumulation of water on undersides which could start to rot - when checking a wood sash, use a pocket knife and probe the underside of the lower rail where it meets the stile, as this is the most probable place for rot.

6) When replacing or repairing rotting timbers or wood, take out the whole piece or, in any case, take out at least two feet of the wood beyond the last visible point of decay.

Wood destroying insects. The number of insects that may damage or destroy wood varies according to location and therefore a short list of common insects will be given and brief indications of type of damage.

Beetles

Bark Beetles - are of many types, the most common being the spruce bark beetle. It normally thrives on freshly-cut lumber but, can do considerable damage to standing timber. There are bark beetles that attack hardwoods found mainly in the [illegible] provinces.

Powerpost Beetles - the most common is the lyctus species which, in the main, attacks hardwoods, usually the sapwood. The eggs are laid on the pores of the wood and the larvae burrow into and through the wood and emerge, usually in June or July, as winged adults and recommence the cycle. The only indication of their presence is the fine powder trail leading from the small hole in the wood (1/12" or 1/16"). In new lumber, this should cause rejection; in lumber already installed, the lumber should be thoroughly inspected to ascertain the extent of the damage (probably by checking the number of flight holes). If damage is slight, the whole surface should immediately be treated with a special compound to kill any eggs that may have been laid and to ensure that any larvae present in the wood are killed. The whole of the building should be so treated as, if the female winged adult is present in the building, any other timber could be damaged. Damaged timber removed should be burnt immediately.

Termites - In this species group are the termite proper and the carpenter ant. However, precautions against termites are suitable for carpenter ants and therefore general descriptions will refer to both. There are over fifty species of termites in the United States, the principal damage being caused by the subterranean termites which cover all but the Northern Mid-West States and the Northern sections of the Eastern States. The other species group is the dry wood termites, found only in the very southern parts of the Southern States including Florida, California, Texas, and New Mexico.

Termites (subterranean) - live in colonies in the ground and live off wood for food; the damage is caused by worker ants who supply the underground colony. At certain times of the year, winged ants (male and female) fly out and establish a new colony. This often occurs when there is a sharp rise in temperature in the outside air. This should be a warning that termites are close at hand and therefore the building should be examined for termite damage. In many parts, especially on the fringes of forest areas, this will occur constantly each year, therefore it is wise to ensure that all buildings are constructed in these areas with adequate termite protection. The principal defense against termites is the concrete foundation; in the case of concrete block foundations cement mortar should be used, for some termites will burrow through lime mortar. All basements should be covered with a concrete slab; in all crawl spaces a 2" ground seal of concrete should be poured. All form lumber must be stripped from the concrete and not left as food for termites.

In areas where termites are very active, metal termite shields are fitted in addition. If nests are discovered, they should be destroyed and sealed off. These notes are included for the sake of presenting the broad picture, but termites are not believed to exist in Nova Scotia.

Carpenter ants can be killed by swabbing the affected timbers with orthodichlorobenzene or carbon disulphide. Care should be taken with carbon disulphide as it is both toxic and inflammable. If a trail of fine sawdust is found anywhere in a house, strip off the siding or finish nearby and check horizontal joints of sheathing for often it is here that evidence of insect attack can be seen.

Marine Borers - The most common of marine borers is the shipworm or teredo, which can do much damage to wood. In the early stages of growth, it is a minute, free-swimming organism which seeks a place on a floating log and buries itself; as it bores, it grows a pair of boring shells, the tail remaining at the entrance to the wood to pump sea water through its system. The borer lives on wood borings and organic matter from the sea water and may vary in size according to the number present from a few inches to as much as four feet, although rarely do they exceed nine inches in length.

No further teredo damage will occur after the wood leaves the water.

Problems of Finishing

In maintenance of a building, one of the most important items is the decoration and finishing of the various surfaces of the buildings. Today, with the trend away from wood in doors, windows and other features, the importance of correct finish treatments for wood seems to be diminishing and, with the advent of the new alkyd, latex, and other new-based paints, the reasons for the older treatments tend to be forgotten.

It is well to remember, however, that although the modern paints may achieve what the makers claim over the short period that they have been in service, it is still questioned whether they will last as long as some of the older, more carefully-applied lead-based paints.

CANADIAN
BUILDING DIGEST
DIVISION OF BUILDING RESEARCH • NATIONAL RESEARCH COUNCIL
CANADA

DECAY OF WOOD

by M. C. Baker

UDC 691.11:620.19

Wooden objects have been recovered from the tombs of ancient kings in a perfect state of preservation, and wooden roof structures have often lasted for centuries without deterioration. Many old wooden implements and pieces of furniture in homes and museums are as strong and serviceable today as they were when made sometimes hundreds of years ago. Pile foundations, too, in water and in soil, demonstrate the durability of wood.

On the other hand, there are Biblical references to fungal decay which indicate that it has been a problem since man first learned to build with wood. At the present time cases come to the attention of the Division of Building Research where extensive rotting has taken place of wood floors and roofs in as little as two or three years. Sometimes, when incipient decay has gone unnoticed, almost complete destruction has occurred in only a few years. It is usually difficult or even impossible to repair such damage, and the only solution may be the complete replacement of the building element involved.

Wood does not decay simply because it is wet, but because it has been attacked by fungi under rather special conditions of moisture and temperature. The disintegration and ultimate dissolution of wood substance, known as rotting, is the result of the growth of fungi in the wood tissue. In order to prevent decay it is necessary to know the nature of the fungi that attack wood and the conditions necessary for their growth. It may then be possible to modify its service conditions or treat the wood to prevent the start of fungal growth.

Nature of Fungi

Fungi are generally regarded as a highly specialized class of plants that exhibit great diversity of form, are exceedingly numerous in both numbers and species, and have the means for incredibly rapid multiplication. They do not possess chlorophyll, and unlike green plants are unable to build up sugar and starch from the carbon dioxide in the atmosphere. They feed on and thus decompose a wide variety of organic food materials. They are reproduced by bodies known as spores, which roughly correspond to the seeds of higher plants except that they are very much smaller and usually produced in much larger numbers.

When the spores of fungi fall on a suitable medium under moist conditions they germinate somewhat in the manner of seeds. The spore wall bursts and a minute tube, called a hypha, grows forth. The hypha branches and the tiny tubes begin to permeate the soil, compost or wood medium on which the hyphae are growing. With wood-rotting fungi the hyphae spread through the wood, disintegrating the cell walls and reducing their strength. The web or mat of tissue formed by the branching hyphae is known as the mycelium or spawn. It may take the form of root-like strands by the aggregation of hyphae, or thick sheets by the matting of the hyphae.

When fungus has been growing for some time and has built up a sufficient mass of mycelium, it usually proceeds to form fruit-bodies, sometimes called sporophores, on the surface of the medium in the form of toadstools, fleshy or woody shelves, or encrusting sheets. Their appearance usually indicates a fairly advanced stage of wood decay. It is the fruit-body on which fresh spores are formed, and their location on the external surface allows for discharge into the air to complete the growth cycle.

The reproductive power of fungi is fantastic when it is considered that a square-foot-area of dry-rot fungus fruit-body can produce five million spores per minute over a period of many days. These microscopic dust-like particles are shed in clouds from the mature fruit-body, and being very light can remain suspended in the air and drift for long distances. There is therefore every likelihood that spores of wood-rotting fungi will be present wherever wood is used.

Conditions for Fungal Growth

Whether or not wood decays will depend on the conditions to which it is exposed and whether these conditions are favourable for fungal growth. There are five essential conditions for germination and growth, and it will normally be possible to prevent wood decay if any one of them is removed. These conditions are listed below:

1. source of infection,
2. suitable substrate (food),
3. moisture,
4. oxygen,
5. suitable temperature.

Source of infection. If infected wood is in contact with sound wood, the disease will spread to the sound wood by normal growth of the fungal hyphae from the decayed wood, even without the production of spores. Infection may also spread directly from soil to wood in contact with it because most soils contain quantities of organic matter in which fungal organisms are growing. Even when there is no contact between sound wood and infected materials, the space between can be bridged by airborne spores, as has already been indicated. Although some locations may be worse than others, it is almost certain that in any area some airborne fungus spores will be present.

Substrate. Wood provides a suitable substrate for fungus growth, and the cellulose, lignin, and other components of the cell walls and wood tissues provide suitable food. Some species of wood are more naturally durable because they contain substances toxic to fungi, and the heartwood of these will only be attacked by certain fungi. It can be generally assumed, however, that no wood is entirely immune to attack if placed in conditions favourable to fungal growth, allowing for some variation in the susceptibility to decay of different kinds of wood. It is possible to eliminate the food supply by treating it with certain substances toxic to fungi but harmless to men and animals. This is the basis of wood preservative treatment.

Moisture. The development of fungi on wood is largely controlled by the moisture content; all wood-decaying fungi require moderate amounts of water for growth. If there should be insufficient moisture, after growth has started, the fungi do not necessarily die, but will probably become merely dormant. Active growth can start again, sometimes years later, when sufficient moisture returns.

It is necessary for the substratum to be moist and the humidity of the surrounding atmosphere to be high for the germination of fungal spores. Wood always contains a certain amount of moisture; air-dried wood may contain as much as 18 per cent, although it is generally considered that wood in this condition is immune to fungal attack. About 35 to 50 per cent moisture is required for wood rotting fungi to flourish, the actual moisture content depending on the species of fungi and the kind of wood. Fungal spores do not germinate readily on wood that has a moisture content below the fibre saturation point, commonly reached at around 25 to 30 per cent. Wood cannot be considered immune, however, until the moisture content is below about 20 per cent, as is the case in most buildings in Canada (CBD's 85 and 86). When wood is put into service at such low moisture contents, subsequent conditions can cause high local moisture contents, which may be conducive to fungi growth. Once started fungi can produce a certain amount of moisture by the chemical decomposition of the wood, and can thus increase the moisture content of the wood if evaporation loss is low.

Oxygen. All wood-rotting fungi require some air for growth, and many species die quickly if they are deprived of it. The air-moisture balance in the cells within the wood, therefore, is a most important factor controlling the susceptibility of wood to decay. Fungi need oxygen for the oxidation of sugars, which they use for growth and the supply of energy. The breakdown of carbohydrates in the respiration process produces water and carbon dioxide.

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If there is no interchange of air, the fungus will die from suffocation by carbon dioxide. For example, when cell spaces are completely filled with water, as they are when wood is immerged in water, the air supply is cut off and growth is stopped. Burial in the ground below the water table will similarly cut off the air supply.

Temperature. The growth of wood-rotting fungi is affected by temperature in much the same way as the growth of ordinary green plants. It is faster in warm weather than in cold. There are variations in the response to temperature, and for each species there is an optimum at which growth is most rapid. Tests by the Forest Products Laboratories and others on a number of species of fungi common in Canada indicate that temperature conditions for optimum growth range from 65 to 95°F. All fungi show little or no growth at freezing temperatures or slightly above, but most wood rotting fungi are not killed by temperatures well below the freezing point. They can withstand the cold of winter in a dormant state and can recommence active growth when temperatures increase again if other conditions are right.

Growth becomes less rapid as temperatures are increased above 95°F and ceases for most fungi at temperatures slightly in excess of 100°F. Prolonged exposure to temperatures slightly above the maximum for growth, or even short exposure to temperatures much above the maximum, can kill fungus completely. The actual death point is influenced by temperature, length of time and moisture content.

The practical conclusion, therefore, is that in most locations where wood is used in building elements it is more susceptible to decay in summer than in winter.

Other Factors. In addition to the essentials for growth of wood-rotting fungi, there are other factors that may have an effect. Light usually has a retarding influence, and exposure to intense light such as bright sunlight can kill the mycelium of some species. Most species grow more vigorously in subdued light, but some do not grow normally in total darkness.

The acidity and alkalinity of the wood can also have an effect. Most wood-rotting fungi flourish on materials that are slightly acid, and very few can tolerate alkaline conditions. Organic acids are produced by fungal growth, thereby increasing wood acidity. This may be a factor in the corrosion of metal fittings in contact with the wood.

Treatment of wood with nitrogenous materials stimulates growth of wood-rotting fungi, and contamination of wood by urine or manure can increase susceptibility to decay.

Effects of Decay

The decomposition of wood by fungi is of two main types, often referred to as brown rot and white rot. In brown rot the cellulose and its related pentosans are attacked while the lignin is more or less unchanged. This causes wood to darken in colour, and to shrink and cross-crack into cubical or oblong pieces that can be readily broken and crumbled between the fingers into a brown powder.

In white rot all the components of the wood, including the lignin, may be decomposed and used by the growing fungus. White rot does not produce cross-cracking, but the wood becomes paler in colour, sometimes in pockets or streaks of various sizes with firm wood in between, and may eventually become a fibrous whitish mass. In some white rots, however, the cellulose may remain intact.

Decayed wood is less dense than sound wood, may suffer a loss of strength even with incipient decay, shrinks excessively on drying, shows changes of colour and often a change of smell. In the advanced stage of decay it may become punky, soft and spongy, stringy, ring-shaked, pitted or crumbly. The loss of weight for brown rot is about 70 per cent, since the lignin still remains, but for white rot total destruction is possible. Even slight decay can reduce the toughness or shock resistance of wood and allow it to break easily under impact although it may still appear hard and firm to the touch. Fungi that cause brown rot usually bring about a more rapid drop in most strength properties than do those that cause white rots, but both types can reduce the toughness of any wood they attack. The fresh and resinous smell of sound wood is usually replaced by a distinctive mushroom odour as wood decays, and some wood-rotting fungi produce characteristic aromatic or sweet smells.

Types of Fungi

By examination of rot and any fruit-bodies that may have developed, wood pathologists can usually identify a species with moderate certainty, but it may sometimes be difficult even for specialists to make such an identification and determine whether the species are active or inactive. Extensive laboratory work may be necessary. Expert advice is essential for detailed determination, but the building practitioner should be generally aware of the fungi that may be involved.

The Forest Products Laboratory of the Canadian Department of Forestry and Rural Development lists five types of building-rot fungi that are of importance. These are *Lenzites saepiaria, Lenzites trabea, Fomes roseus, Lentinus lepideus,* and *Merulius lachrymans.* All can be active agents in the destruction of wood in damp locations, but two of the five are perhaps the most common. *Lenzites saepiaria* is probably the most active destroyer of softwoods and has been identified in many of the rotted wood roofs in Canada. *Merulius lachrymans,* sometimes referred to as the true "dry-rot" fungus, does extensive damage to buildings in Europe and also occurs fairly frequently in Canada. It has great virulence when once established.

Lenzites saepiaria is a brown rot, which in its early stages yellows and softens wood, and may give it a laminated appearance because decay begins and proceeds most rapidly in the spring or sap-wood. Rot may occur in pockets, which merge as decay proceeds. Shrinkage and checking take place both radially and tangentially, gradually reducing the wood to a yellowish-brown friable mass. Fruit-bodies are comparatively small, yellowish or orange yellow at first, later changing to a rusty or dark brown.

Merulius lachrymans grows very profusely when once established on damp wood, producing snowy white mycelial mats from which glistening yellow or lilac coloured moisture drops usually exude. It requires rather constant conditions of temperature and humidity for its growth and thrives best in unventilated places where the air is quite still. Wood decayed by the fungus is pale brown in colour, and becomes broken up into large brick shaped pieces as it dries and shrinks. The decayed wood is easily crumbled to powder between the fingers. Fruit-bodies are formed in shapes somewhat resembling pancakes on horizontal surfaces, but may form shelves on vertical surfaces. The surface of the fruit-bodies is tough and wrinkled, and on it millions of rusty red spores are formed.

From the centres of profuse growth of *Merulius lachrymans* fungus can send out mycelial strands which may pass over or through brickwork, plaster or other building materials. These strands can transport water from the damp place in which the fungus first established itself to wood of low moisture content at some distance, thus wetting the wood and starting new fungus growth.

Conclusion

Dampness is one of the five essential conditions for fungal growth and should be the easiest to control. If dry materials are used in building and moisture can be prevented from reaching or accumulating in wood portions of the finished structure, rotting will be eliminated. Dampness in a building or in some element of a building can be attributed to a lack of consideration during design, poor workmanship during construction, neglected maintenance, or some combination of these. To prevent it the designer needs to pay particular attention to rain penetration, ventilation and condensation, as described in previous Digests. The contractor should protect materials against moisture and take care with construction details to avoid air leakage paths. If the building is reasonably well designed and constructed, little maintenance may be required, but undetected leakage in roofs or drainage systems can provide the damp conditions necessary for rotting. It is therefore essential to have regular inspection and maintenance procedures.

When moisture cannot be controlled or wood has to be placed in wet locations, adequate treatment with wood preservatives will effectively control decay.

BIBLIOGRAPHY

Canadian Woods; their Properties and Uses. Canada, Forest Products Laboratories, Ottawa, 1951.

Findlay, W. P. K. Dry Rot and Other Timber Troubles. London, Hutchinson, 1953.

FLOOR JOISTS — LIVING QUARTERS

Species	Grade	Nominal Size	LIVE LOAD 40 lb per sq ft							
			All Ceilings							
			Joist spacing							
			12 in.		16 in.		20 in.		24 in.	
		inches	ft	in.	ft	in.	ft	in.	ft	in.
Eastern Spruce (2) Balsam Fir Eastern Hemlock	No. 1 (Construction)	2 x 6	9	8	8	10	8	2	7	6
		2 x 8	13	4	12	0	11	2	10	4
		2 x 10	16	10	15	2	14	2	13	0
		2 x 12	20	4	18	6	17	1	16	1
	No. 2 (Standard)	2 x 6	9	2	8	0	7	1	6	6
		2 x 8	13	4	11	10	10	7	9	8
		2 x 10	16	10	15	2	13	7	12	5
		2 x 12	20	4	18	6	17	1	16	1
Jack Pine (3)	No. 1 (Construction)	2 x 6	10	0	9	1	8	5	7	11
		2 x 8	13	7	12	5	11	6	10	10
		2 x 10	17	4	15	8	14	7	13	8
		2 x 12	20	11	19	0	17	7	16	7
	No. 2 (Standard)	2 x 6	9	11	8	7	7	8	7	0
		2 x 8	13	7	12	5	11	5	10	5
		2 x 10	17	4	15	8	14	6	13	4
		2 x 12	20	11	19	0	17	7	16	7
White Pine Red Pine	No. 1	2 x 6	9	5	8	7	7	10	7	1
		2 x 8	12	10	11	8	10	7	9	[illegible]
		2 x 10	16	4	14	10	13	5	12	2
		2 x 12	19	8	17	11	16	7	15	7
	Merchantable and No. 2	2 x 6	9	2	8	0	7	2	6	6
		2 x 8	12	10	11	1	9	11	9	1
		2 x 10	16	4	14	2	12	8	11	7
		2 x 12	19	8	17	11	16	7	15	6
	No. 1 Dimension	2 x 6	8	8	7	6	6	8	6	1
		2 x 8	12	4	10	7	9	6	8	8
		2 x 10	16	4	14	2	12	8	11	7
		2 x 12	19	8	17	11	16	2	14	10
	No. 2 Dimension (4)	2 x 6	6	8	5	10	5	2	4	8
		2 x 8	9	6	8	2	7	4	6	8
		2 x 10	13	0	11	4	10	1	9	2
		2 x 12	16	6	14	4	12	10	11	8
Poplar	No. 1 (Construction)	2 x 6	9	5	8	7	7	10	7	1
		2 x 8	12	10	11	8	10	7	9	8
		2 x 10	16	4	14	10	13	5	12	2
		2 x 12	19	8	17	11	16	7	15	7
	No. 2 (Standard)	2 x 6	8	8	7	6	6	8	6	1
		2 x 8	12	10	11	1	9	11	9	1
		2 x 10	16	4	14	2	12	8	11	7
		2 x 12	19	8	17	11	16	7	15	6

Notes

(1) When either of these species is graded by Western Wood Products Association Rules, the spans of 2 x 6 members shall be reduced as follows:
Construction Grade — 6 per cent.
Standard Grade — 8 per cent.

(2) When Eastern Spruce is graded by Western Wood Products Association Rules, spans for Western Spruce apply.

(3) When graded by Western Wood Products Association Rules, spans for Pacific Coast Yellow Cedar shall apply with the span reductions as in (1)

(4) When graded by Eastern Pine Grading Committee Rules, spans for No. 2 Dimension Grade may be increased as follows:
2 x 6, 2 x 8 — 10 per cent
2 x 10, 2 x 12 — 15 per cent.

FLOOR JOISTS — LIVING QUARTERS

Species	Grade	Nominal Size	LIVE LOAD 40 lb per sq ft							
			All Ceilings							
			Joist spacing							
			12 in.		16 in.		20 in.		24 in.	
		inches	ft	in.	ft	in.	ft	in.	ft	in.
Douglas Fir, Western Larch	Construction (dense and non-dense)	2 x 6	11	0	10	0	9	4	8	8
		2 x 8	15	0	13	7	12	8	11	11
		2 x 10	19	0	17	4	16	0	15	1
		2 x 12	23	0	20	11	19	5	18	4
	Standard	2 x 6	11	0	10	0	9	4	8	6
		2 x 8	15	0	13	7	12	8	11	7
		2 x 10	19	0	17	4	16	0	14	8
		2 x 12	23	0	20	11	19	5	17	10
	Utility	2 x 6	—		—		—		—	
		2 x 8	12	2	10	6	9	5	8	7
		2 x 10	16	8	14	6	13	0	11	10
		2 x 12	19	8	17	0	15	2	13	11
Pacific Coast Hemlock	Construction	2 x 6	10	10	9	10	9	1	8	7
		2 x 8	14	8	13	4	12	5	11	8
		2 x 10	18	7	16	11	15	8	14	10
		2 x 12	22	6	20	6	19	0	17	11
	Standard	2 x 6	10	10	9	10	9	1	8	6
		2 x 8	14	8	13	4	12	5	11	[illegible]
		2 x 10	18	7	16	11	15	8	14	8
		2 x 12	22	6	20	6	19	0	17	10
	Utility	2 x 6	—		—		—		—	
		2 x 8	11	2	9	8	8	8	7	11
		2 x 10	15	5	13	5	11	11	10	11
		2 x 12	18	0	15	7	14	0	12	8
Spruce, all western species Lodgepole Pine, Ponderosa Pine	Construction	2 x 6	9	2	8	0	7	1	6	6
		2 x 8	13	4	12	0	11	2	10	4
		2 x 10	16	10	15	2	14	2	13	0
		2 x 12	20	4	18	6	17	1	15	10
	Standard	2 x 6	7	1	6	2	5	6	5	1
		2 x 8	11	5	9	11	8	10	8	1
		2 x 10	15	0	13	0	11	7	10	7
		2 x 12	19	4	16	8	15	0	13	7
	Utility	2 x 6	—		—		—		—	
		2 x 8	10	1	8	8	7	10	7	1
		2 x 10	13	6	12	0	10	8	9	6
		2 x 12	16	2	14	0	12	7	11	6
Western Red Cedar Western White Pine (1)	Construction	2 x 6	9	2	8	0	7	2	6	6
		2 x 8	12	10	11	8	10	7	9	8
		2 x 10	16	4	14	10	13	5	12	3
		2 x 12	19	8	17	11	16	2	14	10
	Standard	2 x 6	7	4	6	4	5	8	5	3
		2 x 8	10	10	9	4	8	4	7	7
		2 x 10	14	1	12	2	10	11	10	0
		2 x 12	18	2	15	8	14	1	12	10
	Utility	2 x 6	—		—		—		—	
		2 x 8	9	6	8	2	7	4	6	8
		2 x 10	13	0	11	4	10	1	9	3
		2 x 12	15	4	13	2	11	10	10	10
Pacific Coast Yellow Cedar	Construction	2 x 6	10	0	9	1	8	2	7	6
		2 x 8	13	7	12	5	11	6	10	10
		2 x 10	17	4	15	8	14	7	13	8
		2 x 12	20	11	19	0	17	7	16	7
	Standard	2 x 6	8	5	7	2	6	6	5	11
		2 x 8	12	4	10	7	9	6	8	8
		2 x 10	16	1	14	0	12	6	11	5
		2 x 12	20	8	18	0	16	1	14	8
	Utility	2 x 6	—		—		—		—	
		2 x 8	10	11	9	8	8	5	7	8
		2 x 10	14	11	12	11	11	6	10	6
		2 x 12	17	6	15	1	13	6	13	5

CE003321

Notes to Student

1. In undertaking this test you are assisting in evaluating your program of instruction. Your answers to the questions will result in a score being assigned to you. Unless you have had previous exposure to building construction, it is expected that your initial score on this test will be quite low. After you have completed the programmed learning book, you will be asked to repeat this test paper again. You may take as much or as little time as you need to complete the book, so long as it it completed within this term.

The mark made on the second attempt at this paper will be your term mark.

2. Answering the questions should be relatively easy, simply check, or underline your choice or choices in the multiple response questions, or fill in the appropriate words where blanks are left, or complete sketches where this is called for.

SCHOOL OF ARCHITECTURE
NOVA SCOTIA TECHNICAL COLLEGE

NAME:____________________

CONSTRUCTION TERM '

TEST PAFER

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1. What is the simplest function of a building?
   - a) To enclose space
   - b) To separate environments
   - c) To provide shelter
   - d) To provide space for activity

2. The roof is a ____________________ element
   it must support
   - a) live load
   - b) dead load

3. The load bearing member in a wood flat roof is known as
   a) rafter, b) pinlin, c) joist

4. The inclined load bearing member in a wood roof is known as
   a) a rafter b) a pinlin, c) a joist d) a truss

5. The truss uses the principle of ________________________, as well as shortening the effective __________________ of the members.

6. a) The effective span a) is b) is not the actual length of a joist

   b) The area of joist support is known as the a) plate b) support c) bearing d) bridging

7. (Stiffener) (strapping) (belting) (bridging) is required to counteract buckling.

8. The two methods of counteracting buckling in common use are ____________ and___________________________.

9. A method of counteracting buckling is required at
   a) 2'0"o.c. b) 8'0"o.c. c) half span d) at joist ends

10. Between the joist and the bearing surface a
    a) disc b) plate c) platen d) bolt e) pad is located.

11. At junctions between structural horizontal wooden support members and concrete walls it is neccessary to ensure that
    a) The wall is level, b) the wood member is level, c) an airtight joint is made, d) a watertight joint is made, e) it is securely fastened down.

12. For what purpose is an anchor bolt used?
    a) To prevent structure from slipping off supports
    b) To locate structure to supports
    c) To hold structure down
    d) To hold structure up

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13. The basic difference between the two major types of light wood frame construction is that in ________________ frame the studs are continous through the height of the building whereas is ________________ frame the sub floor acts as a surface on which subsequent operations can be carried out
(Western) (balloon) (Eastern) (plane) (surface) (platform) (braced)

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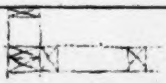
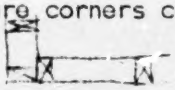
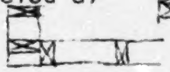
14. How are corners constructed a)



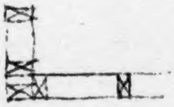
b)



c)



d)



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15. The load carrying components in framed construction are known as
a) studs b) joists c) posts d) lintols e) beams

---

16. Load carrying components, due to material sizes are normally placed.
a) 12"o.c. b) 14"o.c. c) 16"o.c. d) 18"o.c. f) 24"o.c.
g) 30"o.c. h) 4'0"o.c.

---

17. What is the minimum size of lintol required to span an opening 6'0" wide?
a) 2/2"X6" b) 4" X 6" c) 2" X 12" d) 4" X 12" e) 4" X 8"
f) 2/2" X 8" g) 2" X 6"

---

18. A joist hanger is used a) to hang vertical members off joists
b) to support light fixtures c) to connect dissimilar materials together
d) to connect differing sizes of members together e) to give level top surfaces to a groups of members f) to give level bottom surfaces to a group of members. g) to connect joists to headers.
h) to hang joists from other members.

---

19. A floor consisting of 2" X 10" joists @ 16"o.c.is required to span 20'0"
Is it possible to span this distance without additonal support?
Yes No
If your answer was no, what additonal support would you use
a) Concrete beam b) steel joist c) wall, d) beam

---

20. A board foot of wood is a) a piece of wood 12" X 12" X 12"
b) a piece of wood 4" X 8" X 12" c) a piece of wood 4" X 8"
d) a piece of wood 12" X 12" X 1"

---

21. 20' span, 26 joists 2" X 6", how many board feet?

---

22. The continous support bearing on the ground and carrying a wall is known as a a) strip b) pad c) plate d) ribbon e) trench footing.

23. The support member bearing on the ground and carrying a column or post is known as a a) strip b) pad c) plate d) ribbon e) trench f) piloti g) pile footing

---

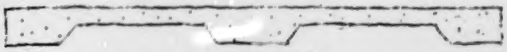
24. The ultimate ability of the ground to carry load is known as

a) spread load
b) ground bearing pressure
c) ultimate ground bearing pressure
d) footing load
e) allowable ground bearing pressure

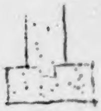
---

25 Footing drains are used to
a) drain off excess water
b) prevent leaks in basements
c) prevent building from floating
d) lower ground water table

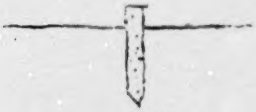
26.



This is a _______________ foundation.



This is a _______________ foundation.



This is a _______________ foundation.

(strip) (pad) (plate) (ribbon) (trench) (piloti))raft) (floating) (caisson)
(bored pile) (driven pile) (friction pile) (end bearing pile)

---

27. Movement of a building takes place
a) vertically
b) horizontally
c) diagonally
d) vertically & horizontally
e) in all directions.

---

28. Concrete is composed of a) sand and cement b) aggregate and cement c) fine aggregate, coarse aggregate and cement d) Cement, water & aggregate e) crushed rock sand, water, cement f) sand, water & cement

---

29. The hardening of concrete is a result of
a) the evaporation of water b) the absorbing of water
c) the entrapment of air within it d) the combination of water with cement

30. The strength of concrete is influenced by
a) The thorougness of mixing b) the amount of cement c) the amount of aggregate d) the amount of air entraped e) the amount of water f) the weather conditions at time of placing.

31. Concrete is (strong) (weak) in tension, and (strong) (weak) in compression.

32. Concrete cover is required over reinforcement to a) Ensure bond b) to prevent spalling c) to protect it form effects of fire d) to protect from corrosion e) for appearance

33. An exterior wall consisting of 2" X 6" studs at 16"o.c. is to be clad with cedar shingles a) it does not require sheathing b) it requires 11/16" boarding c) it requires 3/8" gypsum board d) it requires 5/16" exterior quality plywood.

34. The following materials as applied to wood frame construction are
a) claddings b) veneers
wood, asbestos, steel, aluminum, plastic, slate, clay tile.

35. The following materials as applied to wood frame construction are
a) claddings b) veneers
brick, stone, clay tile, reconstituted stone

36. Cladding is used as
a) A protective finish to the structure
b) An aesthetic skin
c) To waterproof the structure
d) As a primary weather barrier

37. What are the four elements of a wall?

1. ____________________
2. ____________________
3. ____________________
4. ____________________

38. What are the three elements that result in rain leakage.

1. ____________________
2. ____________________
3. ____________________

V

39. In order to keep thermal movement to a minimum should one
    a) keep the building warm
    b) insulate the building thoroughly
    c) keep the building cool
    d) maintain the structure of the building at an even temperature

---

40. Where should insulation be placed in external walls?
    A) Within the wall
    B) On the inside face of the wall
    C) On the outside of the wall

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41. A pitched roof is satisfactory because
    a) It uses overlapping units
    b) It permits ventilation of the roof space
    c) It takes advantage of the effects of gravity
    d) It does not require to be perfectly sealed

---

42. For successful performance a perfect impermeable membrane is required
    a) for all roofs b) for curved roofs c) for flat roofs
    d) for pitched roofs.

---

43. With the current state of technology windows are
    a) Neccessary to admit light
    b) Neccessary to provide ventilation
    c) Neccessary to provide a view
    d) not neccessary

---

44. Large areas of glass in the external walls of a building are undesirable because a) Excessive glare is produced b) Excessive heat gain results c) Condensation occurs on glass d) Cold drafts occur e) They are expensive f) Excessive heat loss occurs g) They leak h) They are expensive to install and maintain.

---

45. Icing will occur on windows a) when outside temperatures fall below 32°F b) when surface temperature of the window falls below 32°F c) when inside temperatures fall below 32°F d) when dew point is reached e) when surface temperature falls below 32°F with condensation present

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46. Thermal breaks are required in windows whose frames are made of
    a) aluminum b) stainless steel c) steel d) plastic e) wood

---

47. The most likely place for a well designed window to leak is at
    a) the head b) the cill c) the jamb d) the glazing beads
    e) the junction of head & jambs f) the junction of frame & glass
    g) the junction of frame & wall

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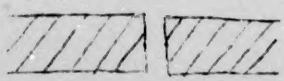
48. The optimum location for a sealant in a window component is
- a) at the outside face of the component
- b) at the inside face of the component
- c) centrally between inside and outside face of component
- d) at both inside and outside faces of the component

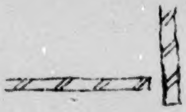
49. Satisfactory sealant joints are achieved by using
- a) as much sealant as possible
- b) as little sealant as possible
- c) an even bead of sealant
- d) a carefully controlled amount of sealant
- e) a sealant bead of controlled shape

50. Sketch two typical sealant joints a) for a butt joint
b) for a right angle joint

a



b



51. An airtight seal between opening leaves of doors or windows and frames is achieved by
- a) Use of gravity
- b) Compression of gaskets
- c) Use of tight fit

52. In a built up roof the waterproofing is provided by
- a) the felt
- b) the topping
- c) the bitumen
- d) the V.B.

53. A built up roof is reinforced with
- a) steel
- b) fibreglass
- c) felt
- d) bitumen

54. Pitch (is) (is not) compatible with asphalt

55. Pitch is not compatible with the following insulations
    a) Fibreboard
    b) Glass fibre
    c) Poly styreme
    d) Cellular glass
    e) Poly urethane
    f) Mineral fibre

---

56. Gravel surfacing on a roof is provided to
    a) Waterproof it
    b) Protect the bitumen from the sun's rays
    c) Act as an aesthetic finish
    d) Act as a traffic surface
    e) Act as fire protection

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57. N.I.S. is (a) satisfactory (b) unsatifactory as a finsished surface for a traffic free roof.

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58. A roof coating is a) superior b) inferior c) equivalent to NIS as a roof finish

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59. Moisture entry from below the roof structure is controlled by
    a) The roofing membrane
    b) the insulation
    c) the structural deck
    d) the Vapour barrier

---

60. Which of these insulation materials can be used exposed to the elements on a roof.
    a) Glass fibre b) Fibreboard c) Poly styrene foam d) poly urethane foam
    e) cellular glass f) straw fibre g) mineral fibre

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61. The surface protection provided for insulation where it is not generally accessible can be a) A water resistant material
    b) A material opaque to U.V.
    c) A reflective material
    d) An elastic material
    e) A heavy material

---

62. Flashings are used to a) provide a neat appearance where the roof joins other elements
    b) provide a robust finish at points susceptible to impact damage
    c) provide a watertight connection at changes in materials
    d) provide a flexible watertight connection at changes in materials.

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63. The top of a cap flashing should be
    a) flat b) sloped c) sloped towards roof d) pitched e) sloped away from roof.